PB83-245225

Effect of Animal Grazing on Water Quality of Nonpoint Runoff in the Pacific Northwest

Agricultural Research Service, Pullman, WA

Prepared for

Robert S. Kerr Environmental, Research Lab.
Ada, OK

Aug 83

U.S. Department of Commerce
National Technical Information Service
NTIS

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

EPA-600/2-83-071
August 1983

PB83-245225

DROPPED HEAD; BEGIN SECTIONS HERE

EFFECT OF ANIMAL GRAZING ON WATER QUALITY OF NONPOINT RUNOFF IN THE PACIFIC NORTHWEST

by

Keith E. Saxton
Lloyd F. Elliott
Robert I. Papendick
Michael D. Jawson
USDA-SEA-Agricultural Research
Washington State University
Pullman, WA 99164

David H. Fortier
USDI-Bureau of Land Management
Coeur D'Alene, ID 83814

6-1/2"
9-1/8"

EPA-IAG-D6-0030
EPA-IAG-78-D-X0249

Project Officer

R. Douglas Kreis
Source Management Branch
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

This study was conducted
in cooperation with
U.S. Department of Agriculture
Pullman, Washington 99164

R. S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-83-071	2.	3. RECIPIENT'S ACCESSION NO. PB83 245225
4. TITLE AND SUBTITLE Effect of Animal Grazing on Water Quality of Nonpoint Runoff in the Pacific Northwest		5. REPORT DATE August 1983
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) K. E. Saxton, L. F. Elliott, R. I. Papendick, M. D. Jawson, and D. H. Fortier		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS USDA-SEA-Agricultural Research Washington State University Pullman, WA 99164		10. PROGRAM ELEMENT NO. ABPC
		11. CONTRACT/GRANT NO. EPA-IAG-D6-0030 EPA-IAG-78-D-X0249
12. SPONSORING AGENCY NAME AND ADDRESS Robert S. Kerr Environmental Research Laboratory U. S. Environmental Protection Agency P.O. Box 1198 Ada, OK 74820		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA/600/15

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This project was initiated to evaluate the effects of summer grazing cattle in the winter precipitation regions of the western intermountain basins of the United States on the quality and quantity of nonpoint surface runoff. Emphasis was placed on erosional, chemical, and bacteriological characteristics of runoff from a typically managed summer pasture to determine the potential contribution of this practice to nonpoint source pollution. The results show that bacterial quality is related to livestock, but there is considerable doubt that indicator bacterial water quality standards developed for point sources are appropriate for assessing non-point source bacterial contamination.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Agricultural wastes Animal Husbandry	Animal Waste Management Environment Non-Point Source	43F 68D

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 148
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement EPA-IAG-78-D-X0249 to the USDA-SEA-AR. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

8316

FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in ground water and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for developing and demonstrating cost-effective land treatment systems for the environmentally safe disposal of solid and hazardous wastes.

This project was initiated to evaluate the effects of summer grazing cattle in the winter precipitation regions of the western intermountain basins of the United States on the quality and quantity of nonpoint surface runoff. Emphasis was placed on erosional, chemical, and bacteriological characteristics of runoff from a typically managed summer pasture to determine the potential contribution of this practice to nonpoint source pollution. This information is useful in determining optimal practices which will lead to the development of Best Management Practices (BMPs).

Clinton W. Hall

Clinton W. Hall, Director
Robert S. Kerr Environmental
Research Laboratory

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

ABSTRACT

Streamflow water quality was intensively studied for three years (1976-1979) on a grazed [21.5 hectares (ha)] and an ungrazed check (0.9 ha) watershed near Potlatch, Idaho. The objective was to identify water quantity, erosion, and water quality from a typical summer grazed watershed in this region of winter precipitation and to identify animal impacts by comparison with the ungrazed watershed. Special emphasis was placed on bacteriological water quality measurements and interpretations.

The study period contained a near-drought year and two more nearly normal years with significant runoff that provided good water quality determinations. Erosion was minimal on the grazed watershed although cattle trails were an obvious source. Chemicals from the grazed and ungrazed watersheds were of low concentrations and quantities and the water quality was not impaired for most uses. Indicator bacterial numbers were often high and were closely related to cattle presence on the watershed. Unexpected persistence of indicator bacteria was found after fall removal of the livestock and significant numbers were found in the spring months after the temperature raised and before grazing began. These results show that bacterial quality is related to livestock, but there is considerable doubt that indicator bacterial water quality standards developed for point sources are appropriate for assessing non-point source bacterial contamination. More research is needed to identify appropriate bacterial indicators for nonpoint runoff. And research is needed to determine the effect of alternative pasture and grazing management on runoff quantity and quality.

This report was submitted in fulfillment of EPA-IAG-D6-0030 and EPA-IAG-78-D-X0249 by USDA-SEA-Agricultural Research under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 1976 to December 1980, and the work was completed as of October 1980.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

CONTENTS

Foreward iii
Abstract iv
Figures vi
Tables viii
Abbreviations and Symbols x
Acknowledgment xii

1. Introduction 1
2. Conclusions 3
3. Recommendations 5
4. Study Objectives 6
5. Literature Review 7
6. Experimental Procedures and Methods 10
    Watershed description 11
    Instrumentation 13
    Watershed operation 14
    Bacterial and chemical methods 15
    Samples Analyzed 17
    Nutrient discharge calculations 17
7. Results and Discussion 21
    Hydrology and sediment 21
    Water chemicals and oxygen 26
    Water bacteria 28
    Parameter response and spatial distribution 31

References 87
Appendices

A. Daily observed precipitation, runoff, and sediment discharge 89
B. Daily climatic data 107
C. Sample and analytical procedures 120
D. Water quality data 129

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

FIGURES

Number		Page
1	Descriptive map of study watersheds topography, land use, and instrumentation	12
2	Example sampling frequency during a typical hydrograph and selected analyses on each sample	16
3	Observed watershed monthly precipitation and normal precipitation (Potlatch, Idaho)	67
4	Accumulative daily precipitation and normal precipitation	68
5	Runoff season hydrologic summary for main watershed, 1976-77	69
6	Runoff season hydrologic summary for main watershed, 1977-78	70
7	Runoff season hydrologic summary for main watershed, 1978-79	71
8	Runoff hydrograph from the main study watershed	72
9	Runoff hydrograph from the check study watershed	73
10	Soil moisture depletion from the grazed watershed	74
11	Rock Creek watershed groundwater levels, 1976-77	75
12	Rock Creek watershed groundwater levels, 1977-78	76
13	Rock Creek watershed groundwater levels, 1978-79	77
14	Water temperature and dissolved oxygen for the main watershed	78
15	Water temperature and dissolved oxygen for the check watershed	79
16	Streamflow hydrograph, fecal streptococci and coliform concentrations, Rock Creek main watershed	80

EPA-287 (Cin.)
(4-76)

Figures (Cont.)

Number		Page
17	Streamflow hydrograph and specific conductivity, Rock Creek main watershed, ...	81
18	Streamflow hydrograph and nitrate concentrations, Rock Creek main watershed	82
19	Streamflow hydrograph and ortho-phosphate concentrations, Rock Creek main watershed	83
20	Typical water quality parameter concentration response, COD, to streamflow during snowmelt, Rock Creek main watershed	84
21	Typical water quality parameter response, total P, to streamflow during a mixed snowmelt and rainfall event, Rock Creek main watershed	85
22	Location and description of sampling sites within the watershed	86

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLES

Number Page

1 Number of Samples by Source for Each of the Water Years of the Project 18

2 Comparison of Actual Data and Interpolated Data Point Integrations during October-December, 1977, Rock Creek Main Watershed 20

3 Monthly Precipitation Data Summary 33

4 Annual Streamflow Summary 35

5 Runoff Event Summary 36

6 Annual Sediment Summary 39

7 Estimated Density and Coverage of Cattle Fecal Deposits on the Rock Creek Watershed at Three Times during 1978 40

8 Nitrogen and P Discharge from the Rock Creek Main Watershed, 1977 Water Year 41

9 Nitrogen and P Discharge from the Rock Creek Check Watershed, 1977 Water Year 42

10 Nitrogen Discharge from the Rock Creek Main Watershed, 1978 Water Year 43

11 Nitrogen Discharge from the Rock Creek Check Watershed, 1978 Water Year 45

12 Nitrogen Discharge from the Rock Creek Main Watershed, 1979 Water Year 47

13 Nitrogen Discharge from the Rock Creek Check Watershed, 1979 Water Year 48

14 Phosphorus Discharge from the Rock Creek Main Watershed, 1978 Water Year 50

15 Phosphorus Discharge from the Rock Creek Check Watershed, 1978 Water Year 51

9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Tables (cont.)

Number Page

16 Phosphorus Discharge from the Rock Creek Main Watershed, 1979 Water Year 52

17 Phosphorus Discharge from the Rock Creek Check Watershed, 1979 Water Year 53

18 Average Concentrations of FC, FS, and TC in Runoff from the Rock Creek Main Watershed, 1977 Water Year 54

19 Average Concentrations of FC, FS, and TC in Runoff from the Rock Creek Check Watershed, 1977 Water Year 55

20 Average Concentrations of FC, FS, and TC in Runoff from the Rock Creek Main Watershed, 1978 Water Year 56

21 Average Concentrations of FC, FS, and TC in Runoff from the Rock Creek Check Watershed, 1978 Water Year 57

22 Average Concentrations of FC, FS, and TC in Runoff from the Rock Creek Main Watershed, 1979 Water Year 58

23 Average Concentrations of FC, FS, and TC in Runoff from the Rock Creek Check Watershed, 1979 Water Year 59

24 Bacteriological Water Quality Standards 60

25 Water Quality Parameter Concentration Responses to Streamflow 61

26 Average Percent Fecal Coverage in the Drainage Sampled Within the Study Watershed, Nov. 4, 1978 62

27 Within Watershed Indicator Bacteria Results 63

28 Within Watershed N and P Results 65

6-1/2"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BOD	-- biological oxygen demand
Ca	-- calcium
Cl	-- Chloride
COD	-- chemical oxygen demand
DIS	-- dissolved
DO	-- dissolved oxygen
EC	-- electrical conductivity
Exch	-- exchangeable
FC	-- fecal coliform
FS	-- fecal streptococci
FS/FC	-- fecal coliform:fecal streptotoccus ratio
K	-- potassium
Mg	-- magnesium
N	-- nitrogen
Na	-- sodium
NH_4-N	-- ammonium nitrogen
NO_2-N	-- nitrite nitrogen
NO_3-N	-- nitrate nigrogen
Org	-- organic
P	-- phosphorus
p	-- precipitation
pH	-- acidity level
Q	-- runoff
Sed	-- sediment
SC	-- specific conductivity
TC	-- total coliforms
TKN	-- total kjeldahl nitrogen
TOC	-- total organic carbon
T-N	-- total nitrogen

UNITS OF MEASURE

a	-- acre
cm	-- centimeter
g	-- grams
ha	-- hectare
in	-- inch
kg	-- kilogram
km	-- kilometer
l	-- liters
m	-- meters

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

mg/l -- miligram per liter
mm -- milimeter
m^3 -- cubic meters
sec -- seconds

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

ACKNOWLEDGMENTS

This study was conducted as a joint effort among personnel of the USDA-SEA-AR, University of Idaho, Washington State University, and local cooperators. Many readily contributed their time and talent because they believed that only through known facts determined by research such as this study will intelligent choices be made. We thank each of these participants.

Those making major contributions to the successful completion of this project, in addition to the report authors, included Dr. Myron Molnau, University of Idaho, who directed the watershed operations and managed all hydrologic and sediment data; Dr. John Mitchell and Mr. Richard Rodgers, University of Idaho, who conducted grass utilization and animal-related studies; Dr. Donald McCool, Mr. Verlan Cochran, Mr. Larry Cox, and Mr. Ray Richmond, USDA-SEA-AR, who provided valuable assistance in field and laboratory techniques and data reduction; and our secretaries, Ms. Mary Jo Rawlins and Ms. Edith Waldher, who provided coordination and word processing. This field study was only possible through the much appreciated cooperation of the land owners, Mr. Floyd Libey and Mr. Ray Tarbox, and rancher, Mr. Fred Meckel, who provided the livestock.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 1

INTRODUCTION

In this age of environmental awareness and increased population density, it is urgent to define and improve stream water quality if streams are to continue to be a source of beauty, recreation, and water supply. Streamflow which emanates as surface runoff from agriculture pastureland is suspected of having less than desired quality because of the obvious possibility of fecal, chemical, and sediment contamination. Cattle grazing occupies a significant portion of the agricultural landscape in much of the nation, with cattle densities ranging from feedlots to many hectares (ha) per animal on the western desert ranges. Management for protection of soil, vegetation, and water resources ranges from (a) total sacrifice and disregard to (b) normal protection for continuous economic production to (c) near disuse or major conservation efforts.

The effect of cattle grazing on downstream water quality with various management schemes is currently very poorly defined. Scientific judgment would indicate that the water quality and flow rates, erosion and sediment production, chemicals, and bacteria could all be altered by the presence of livestock on a watershed and the management practices associated with this agricultural operation. However, there is no method of predicting these effects other than through experimental data obtained by scientific study. These results, when combined with those of related studies, will provide inferences of cause and effects.

The result of not obtaining the environmental impact knowledge of agricultural production operations such as cattle grazing could be potentially devastating should regulations and controls be mandated without scientific basis. Even the uninitiated recognize the fact that every operation on agricultural land will have some environmental and downstream impact, and changes and demands for restrictions and controls are inevitable. It is imperative that scientific facts and documented alternatives be available so that society can make intelligent choices on what controls, if any, are necessary.

This study was conducted to evaluate the effects of cattle grazing on runoff volumes and rates, erosion and sedimentation, and chemical and indicator bacteria concentrations and quantities in the surface runoff discharged from agricultural watersheds in the principle grazing areas of the Pacific Northwest. The purpose of this study was to document these water quantity and quality variables over a period of three years from a small watershed managed in a typical fashion for this region under sustained economic production without obvious resource abuse. The impact

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

of cattle presence was defined by excluding grazing on a smaller, but otherwise similar, grazed watershed. The effects of management alternatives were not evaluated. Although a wide variety of water quality parameters were measured on the analyzed samples (approximately 23 types of determinations), special emphasis was given to the bacterial analyses because the animal presence was expected to have more effect on these than on any other parameter.

This study of agricultural runoff water quality was one of four similar studies cooperatively sponsored by the US-EPA. The other three were located in Ohio, Oklahoma, and Nebraska. Each study location measured water quality from grazed pastureland, but each had different emphasis depending upon the staff and facilities available. This study differed most distinctly from the others by the fact that the study investigated the opposing summer grazing-winter runoff combination.

The report which follows is a summary description of the study objectives; facilities and instrumentation used; data organized by hydrology, sedimentation, and water quality; and interpretations and conclusions. Although much detail is omitted, the summaries in the text and appendices provide sufficient information so that the reader may review the data to substantiate the conclusions or to develop their own. This opportunity for re-interpretation is important because the implication of these findings may likely change in the future, but the carefully documented facts of these observations will remain permanent.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 2

CONCLUSIONS

HYDROLOGY AND SEDIMENT

The three study years encompassed a variety of precipitation amounts and event types from near drought to a near normal snow pack. The mean precipitation quantity for the study period was slightly below the long-term average, but in general the data are quite representative for the study region and certainly will apply throughout a broad region of the west where winter precipitation and summer grazing dominate.

Surface runoff, whose quality was the object of this study, were 199 and 136 millemeters (mm) of the 676 and 516 mm (near normal) of precipitation for the main watershed for the two near-normal years, or about 20 percent of the precipitation. The quantity from the small, upland check watershed was only one-third of this amount. The important feature was that adequate surface runoff occurred from both the main and check watersheds and that the water quality of both areas was well defined. Because of the difference in size and topographic setting, significant natural differences in runoff volume was expected and no attempt was planned or conducted to relate runoff quantities to watershed treatments of livestock grazing.

Erosion and streamflow sediment were much less from these pasture lands than from similar tilled agricultural lands. Average sediment yields were only 382 kilograms per hectare per year (kg/ha/yr) from the main watershed for the study period compared with an average of 5,900 kg/ha/yr for a typical nearby tilled watershed during a study period of 1961-65. But the check watershed averaged only 19 kg/ha/yr for the study period, thus it showed much less erosion and sediment transport than the main watershed. Part of this reduced sediment from the check watershed was obviously associated with the reduced surface runoff, but beyond that the observations showed that cattle trails and trampling within the main watershed contributed to the amount of sediment. Several trails on the broad main watershed slopes became small interceptor ditches from surface flow upslope and eroded several centimeters (cm) in depth and width. Several shorter trails within the stream alluvium leading to water places eroded even more. And the small stream banks (most less than 25 cm) had some deterioration due to trampling during grazing and watering. No quantitative assessment was made of these cattle effects and they appeared to be not highly significant to the overall water quality, although this is certainly a quality aspect that could be altered by management techniques of controlled cattle traffic.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

INDICATOR BACTERIA AND NUTRIENTS

Total coliforms (TC) in runoff from grazed and ungrazed areas in the Pacific Northwest did not correlate with the presence or absence of animals. Fecal coliform (FC) and fecal streptococcal (FS) numbers were elevated in runoff from the grazed area when cattle were present above that when they were absent. However, even after animals were absent from the area for several months, FC numbers were elevated in the runoff above recommended levels of 200/100 ml (FC) and 1,000/100 ml (TC) for primary contact. In fact, FC and FS numbers appeared to increase from less than 100/100 ml to several thousand per 100 ml in the runoff from the grazed area for several months in the spring during warm, wet weather after animals were removed the previous fall. Almost three years of cattle absence were required for FC numbers in runoff from the check watershed to be consistently below the maximum recommended numbers for primary contact. The data indicate that the use of conventional FC/FS ratios or FC numbers in runoff as a measurement of recent fecal pollution by cattle on a grazed area is of limited or no value. FC/FS ratios of 1, which indicate recent animal fecal pollution, were found after animals had been removed for several months.

Nitrogen (N) and phosphorus (P) deliveries from the watersheds were low—generally much lower than from areas used for other agricultural purposes. Total-N losses from the grazed area were 3.8 and 3.8 kg/ha during water years 1978 and 1979, respectively, while total-P losses during the same periods were 1.29 and 0.93 kg/ha, respectively, with very low losses of ortho-P. More N fell on the grazed watershed in precipitation than was lost in the runoff.

SECTION 3

RECOMMENDATIONS

This research project provided hydrologic, erosion, and water quality information from a specific site, with one management level, and for minimal study years. While these baseline data are extremely useful for general recommendations that water quality is quite good from pasture land of moderate grazing and management, additional research must be conducted to determine the effect of management practices on sediment, chemical, and bacteriological water quality parameters and to establish bacterial water quality standards for non-point sources. Only through carefully planned and documented studies with varying management levels and techniques will it be possible to adequately understand the effect of management options on local and downstream water quality.

Research is desperately needed to determine the meaning of FC and FS numbers in runoff from nonpoint sources such as grazed areas. This study indicated that these organisms multiplied on the pasture during warm, wet weather several months after the animals were removed. Voluminous literature indicates that pathogenic microorganisms, which the presence of these organisms indicates, cannot survive for long periods outside the warm-blooded host. While the numbers of FC and TC in runoff exceeded those recommended for primary contact, the situation on the watershed should not present a health hazard. Fecal coliform and TC numbers in runoff as defined for point sources do not appear to be viable water quality criteria for non-point sources.

Chemicals such as N and P in runoff from those areas were below levels that would usually be of environmental concern. Grazing areas in the Pacific Northwest, managed as the area described in this report, should not present chemical environmental hazards. Future studies should concentrate on bacteriological processes and interpretations for potential health and environmental hazards.

SECTION 4

STUDY OBJECTIVES

This study was conducted to evaluate the effects of cattle grazing on runoff volumes and rates, erosion and sedimentation, and chemical and bacteria concentrations and quantities in the surface runoff discharged from agricultural watersheds in the principle grazing areas of the Pacific Northwest. The purpose of this study was to document these water quantity and quality variables over a period of three years from a small watershed managed in a typical fashion for this region under sustained economic production without obvious resource abuse. The effects of management alternatives were not evaluated but the impact of cattle presence was defined by excluding grazing on a smaller, but otherwise similar, grazed watershed. Although a wide variety of water quality parameters were measured on the analyzed samples (approximately 23 types of determinations), special emphasis was given to the bacterial analyses because the animal presence was expected to have more effect on these than on any other parameter.

SECTION 5

LITERATURE REVIEW

The effect of cattle grazing on receiving stream water quality has been a subject of some concern. While research in this area has been limited, some studies have addressed this pressing need. There have been related studies of runoff water quality from native prairie and forested areas and studies on the effect of fertilization of grasslands on runoff water quality. However, most of these studies were conducted in areas with a summer rainfall climate.

Timmons and Holt (1977) found that average annual total-N and total-P losses from a native prairie in the upper midwest were 0.8 and 0.1 kg/ha, respectively. In North Carolina, Kilmer et al. (1974) studied nutrient losses from two small steep grassed watersheds fertilized with a total of either 112-48-24 or 448-192-24 kg/ha of N-P-K, respectively. They found annual total-N losses in the runoff were 3.28 and 12.08 kg/ha and that P losses were 0.15 and 0.27 kg/ha, respectively, for the low and high fertilizer rates. Timmons et al. (1977) measured total N and P losses in runoff from an aspen birch forest watershed and found that annual N losses ranged from 1.13 to 2.12 kg/ha while total-P losses ranged from 0.13 to 0.30 kg/ha with ortho-P and organic-P being almost equal. These studies showed that N and P losses in runoff were low in runoff from grasslands and forests; and while fertilization may have increased these losses somewhat, moderate fertilization did not cause large increases in nutrient losses in runoff. From a diverse use watershed located in the Georgia Coastal Plain, Asmussen et al. (1979) found NO_3 plus NO_2-N and ortho-P losses ranged from 0.14 to 0.24 and 0.141 to 0.144 kg/ha/yr, respectively.

The studies that have reported on nutrient losses in runoff from grazed watersheds generally report that the effects of grazing on water quality are minimal. Thomas and Crutchfield (1974) studied several agricultural watersheds and found that the highest nitrate-nitrogen (NO_3-N) concentrations were in runoff from a watershed that was 98 percent pasture. However, the highest NO_3-N concentrations they measured were 6 ppm. P levels were low and P concentrations correlated with the geology of the area from which the runoff originated while NO_3-N levels correlated with land use. Chichester et al. (1979) studied nutrient losses in runoff from grazed and winter feeding areas in Ohio and concluded that chemicals in runoff from those areas did not exceed water quality standards. In Oklahoma, Olness et al. (1975) examined runoff quality from rotational grazed and continuously grazed watersheds and found that annual N loads from the management systems were 1.59 and 7.87 kg/ha, respectively, while P was 1.27 and 4.6 kg/ha, respectively, while Menzel et al. (1978) reported similar data for this area. The more intensive grazing caused greater N and P losses. These N contributions would not seem excessive when one considers that Olson et al. (1973) found that N in the rainfall was 5.6 to 15.7 kg/ha/yr going from west to east in Nebraska, and Schuman and Burwell (1974) reported the annual N delivery in rainfall in western Iowa was 7.26 kg/ha.

The effect of cattle grazing on runoff water quality has received limited attention. Kunkle (1970) compared TC and FC contributions from a grazed pasture and a hay field in Vermont. He found that cattle grazing contributed FC to the runoff and concluded that FC were better indicators of animal pollution than TC. FC counts from the ungrazed hay field that he studied ranged up to 1,000 organisms/100 millileters (ml). In 1976, Buckhouse and Gifford simulated rain on small grazed and ungrazed runoff plots. They found no significant differences between numbers of fecal indicator bacteria in the runoff from the grazed and ungrazed plots. They did show that FC survived in a "cowpie" beyond 18 weeks. Stephenson and Street (1978) studied the effect of cattle grazing on stream-water quality in southern Idaho and found maximum FC counts soon after the introduction of cattle. At several sites, stream FC counts increased from 0 to 2,500 organisms/100 ml. After cattle were removed, the FC counts in the stream remained high for several weeks to three months. They also found that TC numbers correlated poorly with FC numbers. Generally, runoff from a cattle-grazed area, when compared with an ungrazed area, will show increased sediment and numbers of indicator bacteria (Milne, 1976; Robbins et al., 1972). Robbins et al., (1972) compared FC counts in runoff from a grazed and ungrazed watershed in North Carolina and found that the two averaged 30,000 and 10,000 organisms/100 ml, respectively. Schepers (1980) monitored water quality from a large, diverse-use watershed and noted that the majority of the runoff and baseflow water samples exceeded FC standards for recreational water quality. They concluded that it may be inappropriate to use FC numbers as a parameter for nonpoint source water quality, but the FC/FS ratios were less than one most of the time, indicating the source was nonhuman.

Doran and Linn (1979) conducted a comprehensive three-year study in Nebraska on the effect that grazing animals have on fecal bacteria in runoff water. They found that FC bacteria in the runoff assessed grazing impact and that bacteriological indicator counts in runoff from the grazed and ungrazed areas generally exceeded recommended water quality standards. They concluded that recommended water quality standards for a point source may not be definitive for a nonpoint source. In their study, FC numbers were five to ten times higher in runoff from the grazed area than from the nongrazed area and the FC/FS ratio was 11 times that of the nongrazed area.

There are some useful data on the effect of the environment and persistence of indicator bacteria and organisms classified as fecal streptococci. Van Donsel et al. (1967) found the 90 percent reduction time for FC in soil was 3.3 days in summer and 13.4 days in autumn while the FS

TYPING GUIDE SHEET

90 percent reduction time was 2.7 days in summer and 20.1 in winter. They found evidence of aftergrowth of nonfecal coliforms in the soil. Other results were presented showing that some enteric bacteria can grow in an environment approximating that of a clear mountain spring (Hendricks and Morrison, 1967). Kibbey et al. (1978) found cool, moist conditions prolonged the survival of *Streptococcus faecalis* in soil for at least 12 weeks. In another study, Stephenson and Rycert (1981) found stream sediments in southwestern Idaho could contain large quantities of *E. coli*. They found stream sediments contained 2 to 760 times more *E. coli* than the overlying water. They also found that more than 80 percent of atypical colonies growing on an FC medium tested positive as *E. coli* (Rycert and Stephenson, 1981). They pointed out the potential for significant errors if these organisms are disregarded.

Geldreich (1976) presented a classic discussion on the behavior of indicator organisms, and obtainment and use of FC and FS data. He concluded that FC/FS ratios of 4/1 or higher show human fecal contamination while other warm-blooded animal fecal contamination shows FC/FS ratios of 0.6 or less. As sample storage is prolonged or as the contamination moves downstream, the FC/FS ratio will increase from 0.7 to 3.0 because *S. bovis* and *S. equinus* die off rapidly in samples containing fecal contamination from nonhuman sources. He noted that *S. faecalis* var. *liquifaciens* should be considered ubiquitous as it can exist for extended periods in soil, irrigation water, and other waters below 12° C and concluded that FC/FS ratios using FS numbers below 100 are probably useless. He also cited examples that FS can be routinely isolated from vegetation. Later, Geldreich (1981) questioned the use of TC in water-quality studies. Skinner et al. (1974) questioned the use of the FC/FS ratio for nonpoint source studies; however, the numbers of FC and FS they found were generally low.

The existing data are sketchy on the effect of cattle grazing on runoff water quality, and few studies have followed bacterial and chemical quality of runoff from these nonpoint sources on a year-round definitive basis, especially in a summer-grazed winter rainfall climate area. The purpose of this 3-year study was to determine the effect of grazing on runoff water quality in a winter rainfall climate.

EPA-287 (Cin.)
(4-76)

SECTION 6

EXPERIMENTAL PROCEDURES AND METHODS

A paired watershed design was selected to study the water quality impact of animal grazing. The main watershed with an area of 21.5 ha [53.1 acres (a)] was summer grazed with management typical of this region. A check watershed of 0.9 ha (2.2 a) adjacent to the main watershed and a part of the original pasture was fenced to exclude all cattle. These two watersheds were intensively instrumented for complete hydrologic, sediment, and water quality measurements, and were continuously monitored for the period December, 1976 to July, 1979.

The watersheds were carefully selected to be generally representative of the partially forested grazing areas of the Pacific Northwest. The level of recent and current management was of particular interest because management was not to be varied but was to be typical (i.e. most representative) such that neither the worst nor best case was represented. The areas studied met these criteria.

The pasture was grazed at a rate that fully utilized the grass production which produced overgrazing in dryer years but yet not beyond sustained use over a period of years. Little management for grazing distribution or to prevent cattle contact with the stream was done, but this is typical for this region of open pasture, summer grazing. The cattle were usually removed in late October and returned to the pasture in late May. The actual watershed management was carefully recorded and monitored through cattle numbers, forage production and utilization, cattle habits and movements, and dung distribution.

The small check watershed was fenced at the outset of the study and grazing was prohibited during the remainder of the study other than an occasional deer and a calf that broke in for one day during the first summer. No attempt was made to remove existing manure at the study initiation, thus the animal effects were a decaying function from their last presence in October, 1976. To approximately maintain the grass quantities similar between the two watersheds and keep the presence of cattle as the only major difference, the check area grass was mowed, baled, and removed about midsummer each year, after most vegetative growth had occurred.

WATERSHED DESCRIPTION

The main and check watersheds are shown by the planimetric map of Figure 1. The watersheds are located in northern Idaho, 6.4 kilometers (km) [4 miles (mi)] due south of Potlatch, Idaho, which is 26 km (16 mi) north-northwest of Moscow, Idaho. The fence corner shown in the lower right of Figure 1 is near the south-east corner of Section 25, Range 5 West, Township 41 North. The watersheds are in the upper reaches of the Rock Creek drainage which is a tributary of the Palouse River with confluence near Potlatch, ID.

The climatic setting is typical of the mountain foothills throughout much of the west. Average annual precipitation at the study site is approximately 635 mm [25 inches (in)]. There is significant variation in average precipitation amount and form across the region due to elevation and location. The annual precipitation distribution shows that most precipitation occurs in the winter months, November to April, in the typical western Mediterranean type climate. This has significant implications to this study where the cattle were present during the dry summer season when surface runoff seldom occured. Additional climate data are provided in subsequent sections.

The watershed topography is mildly sloping (4 to 8 percent) in the mid- and lower portion and steep (15 to 25 percent) in the upper wooded region. The check watershed is all mildly sloping and all open grassland. The drainage pattern and watershed boundaries are well defined throughout except on the north-east boundary of the main watershed and southern boundary of the check area where the gently changing slopes caused some minor definition difficulty.

The watersheds typify the transition region between the nearly complete farmlands and arid grasslands at the lower elevations to complete forests in the higher elevations. The main watershed open pasture area had been cleared from forest in the early part of this century and farmed a number of years, probably largely in winter wheat. In 1968, this field was reseeded to pasture grasses and has since remained in continuous summer pasture with the same ownership and manager. The check watershed represents the same conversion from farming to pasture. The woodland pasture area in the upper main watershed is moderate dense fir and pine timber and brush which has had some timber removed over the years (none recently) and provides very little grazing.

The watersheds are within a 65 ha (160 a) pasture which is primarily in timber and brush to which the cattle had access. The main watershed area of 21.5 ha (53.1 a) is composed of 12.3 ha (30.4 a) open pasture, 9.2 ha (22.7 a) woodland pasture and 2.2 ha (5.4 a) logged pasture. The ungrazed check watershed of 0.9 ha (2.2 a) is all open pasture, but of course was not grazed. Fecal analysis and time-and-movement observations indicate that the cattle obtained 50 to 60 percent of their annual grazing on the main watershed. The logged pasture in the lower left of Figure 1 was owned by the adjacent rancher. All large timber had been removed, which left the area in

EPA-287 (Cin.)
(4-76)

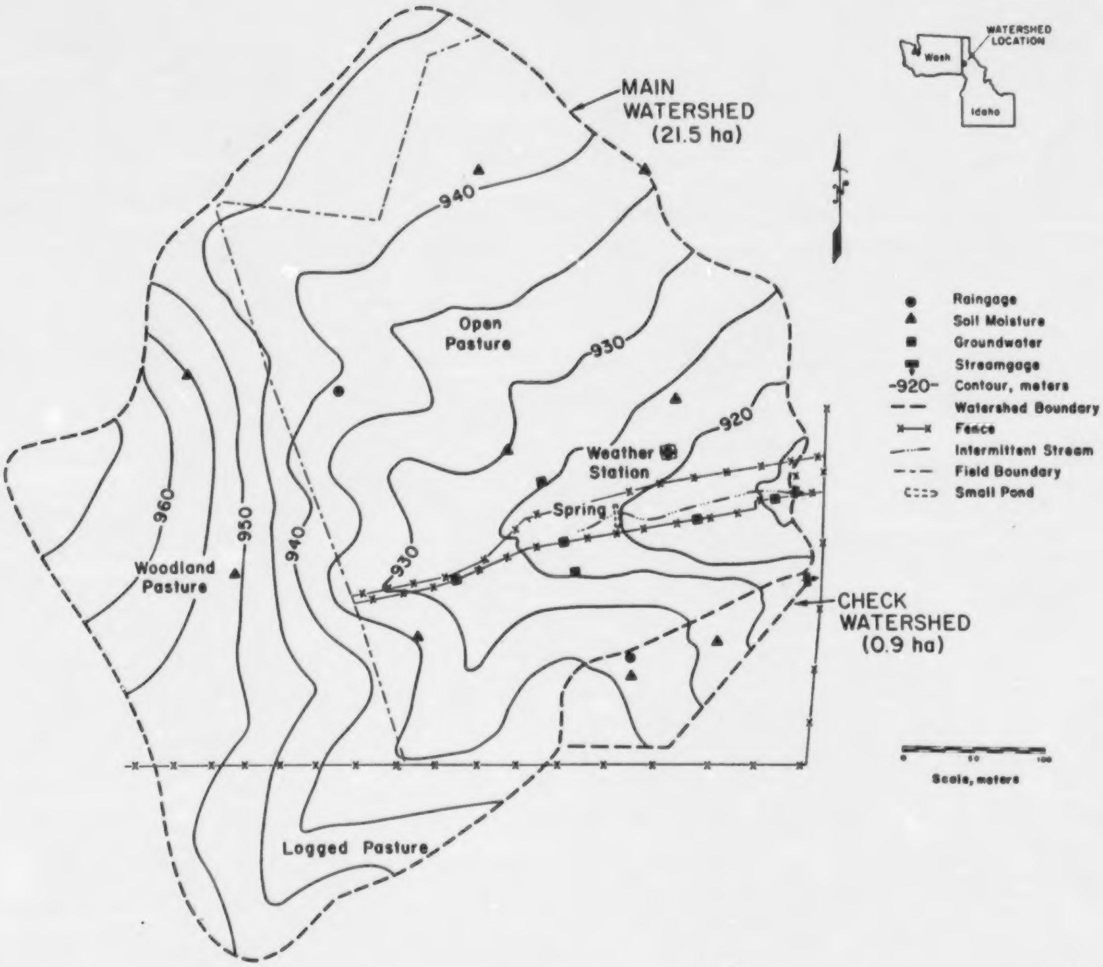

MAIN WATERSHED (21.5 ha)
CHECK WATERSHED (0.9 ha)
WATERSHED LOCATION
Wash
Idaho
N
Open Pasture
Woodland Pasture
Logged Pasture
Weather Station
Spring
960
950
940
930
920
● Raingage
▲ Soil Moisture
■ Groundwater
Streamgage
-920- Contour, meters
Watershed Boundary
Fence
Intermittent Stream
Field Boundary
Small Pond
0
50
100
Scale, meters

Figure 1. Descriptive map of study watersheds topography, land use, and instrumentation.

brush, stumps and slash, and small grass patches. The area was used for horse pasture sporadically throughout the year. This area produced only minimal streamflow as observed near the fence boundary and the researchers believe it had minimal influence on the water quality at the main watershed grazing site because of its small size and distance from the main gaging weir.

The watershed soils are composed of about 100 to 125 cm (40 to 50 in.) of silt loam loess overlying decomposed granitic bedrock. The Taney series occupies the flatter areas north of the main watershed drainage and the very upper ridge area on the west boundary. The Santa series is on the midslope section and all of the check watershed area. The Stanford series is an alluvium of loess derivation and formed a narrow strip along the main watershed drainage up to the woodland pasture. Santa (frigid typic Fragiochrepts) and Taney (frigid boralfic Argixerolls) are very similar and as mapped on the study watershed are generally 60 to 70 cm (24 to 28 in.) of silt loam underlain by silty clay loam to a depth of 107 to 122 cm (42 to 48 in.) where decomposed granitic bedrock begins and progressively becomes less decomposed and more massive with depth.

The loess has good water holding capacity and is moderately well drained. The entire loess mantle is usually recharged to field capacity by winter rains and deep percolation into the bedrock causes local perched water tables, springs, and continuous seepage flow in the main watershed channel during the spring and early summer months. The check watershed had very little evidence of this effect other than some wet zones in the lowest swales. Soil moisture was generally adequate until mid-summer when the shallow rootzone approached the wilting point (see report section on soil moisture). The soil fertility level is marginal and showed significant response to moderate rates of applied fertilizer.

The pasture vegetation was composed largely of brome, fescue, and bluegrass. Grass production was measured in 1978, a near normal precipitation year. The main watershed was separated into a north and south unit at the principal channel. The north unit produced 6,400 kg/ha and the south unit only 2,400 kg/ha, as determined by small, random exclosures. Grazing utilization was approximately 60 and 80 percent, respectively, for this particular year.

INSTRUMENTATION

The principle instrumentation installed on the watershed is shown in Figure 1. Precipitation was measured with five gages. A propane-heated tipping-bucket gage with an adjacent non-recording standard gage were located at the weather station and on the check watershed. A mechanical recording gage was located in the upper (west) portion of the main watershed. The recording and tipping-bucket gages were snow-shield equipped. Runoff on the main watershed was measured with a 2:1 broad-crested v-notch weir formed from aluminum, and water levels were measured with a mechanical strip-chart recorder. The check watershed weir was a small scale SCOV-weir (complex shape and laboratory calibrated) formed of metal, and water levels were measured with two mechanical strip-chart recorders. Both weirs were volumetrically calibrated over the measurement range where nearly all flow occurred and agreement was close to published calibrations.

Both runoff weirs were covered with an instrument house with the weir accessible through a floor trap door. Both the house and weir were heated for winter operation. A Federal Interagency PS-69 pumping sampler was installed in both instrument houses to automatically obtain dual samples at preprogrammed intervals (hourly during surface runoff, twice each day for base flow). One sample was for sediment analysis, the other was for chemical and bacterial analysis. Those pumping samplers were modified to provide a complete system of flushing using current stream water (no backflush tank) to minimize contamination between samples or foreign quality water and to have minimal disturbances to the stream. The sample intakes were attached to the upstream weir face. Dual samplings obtained by the PS-69 sampler and by direct hand sampling showed essentially identical chemical and bacterial results.

Additional instrumentation to complete the hydrologic and climatic data regions included neutron soil moisture access tubes at nine sites as shown in Figure 1, six groundwater wells in the stream alluvium, and a complete weather station. The weather station included air temperature and humidity, wind travel and direction (3-m height), soil temperature profile, pan evaporation with anemometor, solar radiation, soil frost tubes, and the two raingages. All meteorologic instruments (except the evaporation pan), both tipping bucket raingages, both weir water levels, and stream water temperature gages were all recorded on an electronic data logger.

WATERSHED OPERATION

All watershed instruments were operated continuously and sampling was on a regular frequency from December, 1976 to July, 1979. During the summer months (about May 1 to October 30), approximately 45 to 55 cows with calves grazed the pasture containing the main watershed. Specific details of the forage production, grazing, and fecal distribution were monitored by range scientists and are reported in a subsequent section. Many auxillary measurements were made at various times such as snow depths, infiltration rates, flow rates and water samples at other locations in the watersheds, decomposition, and fecal bacteria, etc. Although many of these are not reported or summarized in this report, they provided necessary insight for the interpretations and conclusions which follow.

Essentially all watershed management decisions were left to the rancher to continue in a fashion similar to previous years. Cattle were brought to and removed from the pasture according to grass and weather conditions. The watershed pasture areas were fertilized in the spring of 1977 and 1978, with 62 and 78 kg/ha [55 and 70 pounds (lbs)/a] of N, respectively. No fertilizer had been applied in recent years but moderate application amounts are a common practice by area ranchers. Some supplemental water and feed was

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

supplied to the cattle in the late summer months, but these operations were small and likely had no effect on any of the study measurements.

Cattle grazing was by 44 and 58 animal units during the 1977 and 1978 summer periods, respectively. Primarily, these were cow and calf combinations with about 10 to 15 yearlings. Because of the drought in 1977, some cattle were removed before the end of the grazing season. Cattle numbers remained constant in 1978.

The grazing habits of the cattle were recorded visually and by diet analyses of fecal samples. Preliminary results showed that nearly all grazing was on the watershed in the early summer. By midsummer, approximately 40 percent was from the woodland species; and by late summer, when the watershed grasses had matured, approximately 60 percent was from the woodlands. This pattern had some implications to the manure deposition, but loafing and water habits also played a significant role.

BACTERIAL AND CHEMICAL METHODS

When stream flow increased above baseflow on the main grazed watershed, water samples were collected automatically on an hourly basis during the event. Baseflow samples were obtained at least twice daily. There was no baseflow on the check watershed; samples were collected automatically on an hourly basis when significant runoff occurred.

Water samples analyzed for an event consisted of the hourly samples obtained on the rise and peak with sufficient samples being analyzed on the recession for event characterization . The water samples were held at 4 C before analysis; analyses for bacterial content were conducted in less than 24 hours after sampling. All analyses were conducted according to standard techniques. Analytical and sample handling procedures are shown in Appendix C.

All runoff and baseflow samples were analyzed for TC, FS, FC, NO_3-N, dissolved ammonium (NH_4^+), ortho-P, specific conductivity (SC), chlorides (Cl^-)), total organic carbon (TOC), chemical oxygen demand (COD), pH, and dissolved oxygen (DO). Many of the samples were examined for total Kjeldahl-N, total-soluble Kjeldahl-N, total hydrolyzable-P, total soluble hydrolyzable-P, total-P, total dissolved-P, biochemical oxygen demand (BOD), sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg). Sediment P, organic P exchangeable sediment NH_4^+, organic N and sediment (SED)-N were calculated.

Groundwater sampling wells, 4-cm inside diameter, were established at six locations in the main watershed (Figure 1). At selected times during the year, about one liter of water was pumped from the wells and discarded, they were allowed to refill, and water samples were obtained. The samples were analyzed for NO_3-N, NH_4^+-N, total Kjeldahl-N, ortho-P, total-P, TOC, COD, pH, EC, Cl^-, Mg, Ca, Na, and K.

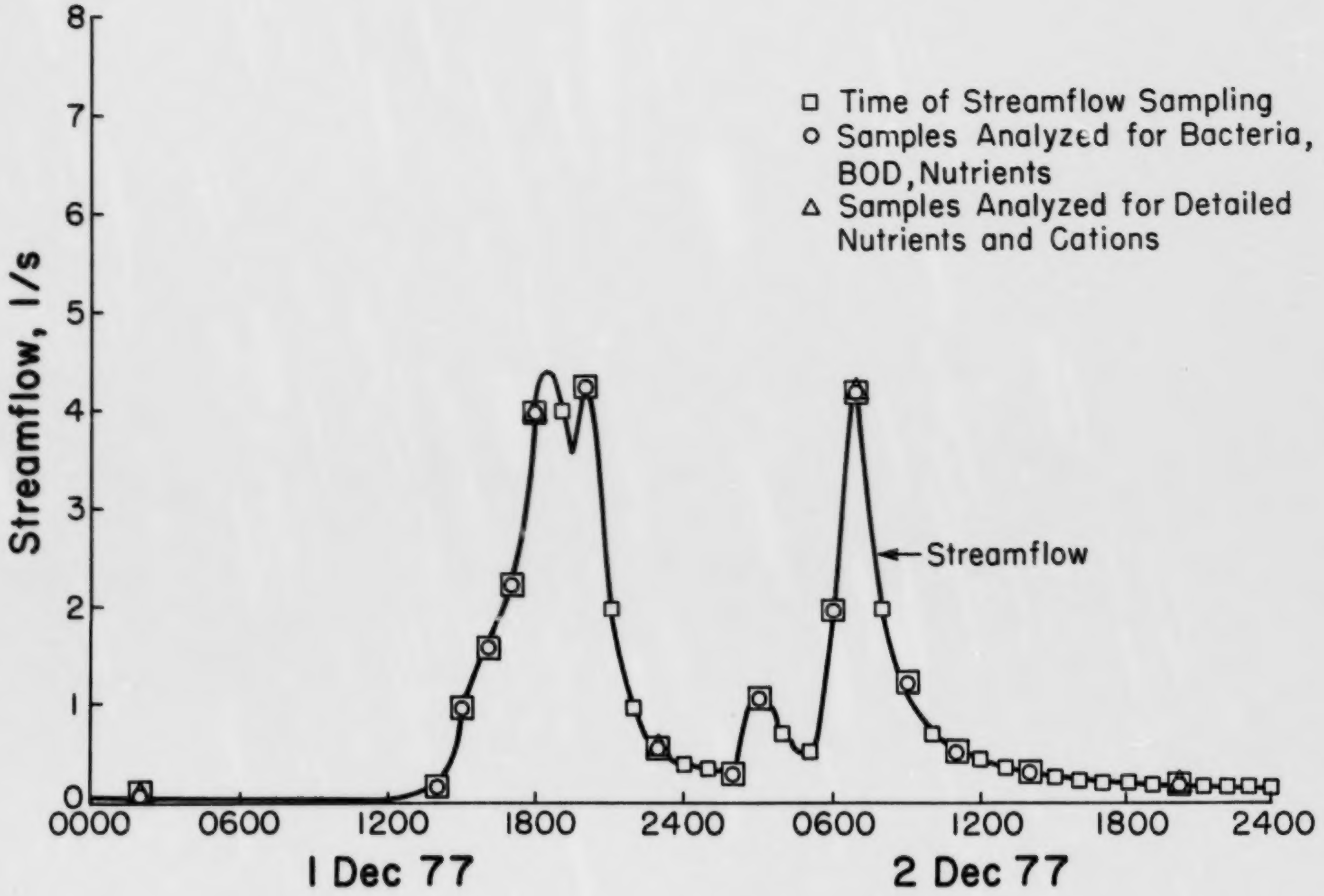


Figure 2. Example sampling frequency during a typical hydrograph and selected analyses on each sample.

TYPING GUIDE SHEET

At the initiation and termination of the study, soil cores were obtained from ten selected areas within the watershed to determine any soil chemical changes that occurred during this study. The soil sampling sites are shown as the soil moisture sites in Figure 1. One sampling site between the spring and streamgage site is not shown in Figure 1. The soil cores were taken to depths of 180 cm (or bedrock) at 15-cm increments. Soil moisture, NO_3^--N, NH_4^+-N, and ortho-P were determined on these samples.

Precipitation samples were collected in 10 x 10 cm plastic freezer containers mounted on top of a post which was 1-1/2 m high. The containers were changed often to avoid contamination. The precipitation samples were analyzed for NO_3^--N, NH_4^+-N, pH, and if sample volumes were adequate, for total Kjeldahl-N. In the spring and summer, some precipitation samples were discarded because of contamination by bird manure.

SAMPLES ANALYZED

The water quality and sediment samples were obtained by both pumping samplers and hand collection. Many more samples were collected than needed, then a series of samples were selected for analysis based on the hydrograph development to provide adequate coverage. Table 1 provides a summary of samples analyzed.

During the first water-year (1977) of this study (December 21, 1976 through September 30, 1977), a total of 461 water quality samples and 411 sediment samples were analyzed, as this was a near drought year. Although the watershed was not fully instrumented for sampling until December 21, 1976, the fall was very dry and two insignificant events were missed. For water-year 1978 (October 1, 1977 through September 30, 1978; precipitation close to normal), a total of 927 water quality samples and 1128 sediment samples were analyzed. During water-year 1979 (October 1, 1978 through July 1, 1979; precipitation slightly below normal), a total of 687 water quality samples and 870 sediment samples were analyzed. While the 1979 water-year was terminated July 1, 1979, no events were missed because there was inadequate precipitation for runoff to occur from the watershed during the remainder of water year 1979.

Because most of the precipitation in the Pacific Northwest occurs in late fall, winter, and early spring, during the three years of the study, only 22 of the 1,447 runoff samples analyzed from the grazed watershed were obtained while cattle were present in the spring, summer, and early fall. The source of the water samples analyzed during the three-year study period are shown in Table 1.

NUTRIENT DISHCARGE CALCULATIONS

Two methods of numerical integration of streamflow with chemical concentrations were tested. The first method involved graphing the

EPA-287 (Cin.) (4-78)

TABLE 1. NUMBER OF SAMPLES BY SOURCE FOR EACH OF THE WATER YEARS OF THE PROJECT

	Sample source				
Water year	Grazed (main) watershed	Ungrazed (Check) watershed	Precipitation	Within watershed	Groundwater
	----Number of water quality samples obtained from each area-----				
1977	356	41	48	--	16
1978	627	162	75	24	39
1979	464	121	46	24	32
	------Number of sediment samples obtained from each area------				
1977	368	41	-	2	-
1978	898	205	-	25	-
1979	662	160	-	49	-

hydrograph, which was previously defined by straight-line segments from the continuous stage record, and plotting the chemical concentrations on the same graph. Then a curve was sketched which best defined a continuous concentration curve for the duration of the hydrograph, points read from this detailed concentration graph to provide adequate straight-line interpolation throughout, and integration performed by multiplying computed water volumes between concentration midpoint intervals times the point concentration. This graphing and re-entry of concentrations was a laborous process.

With frequent streamflow sampling (hourly during significant flow rates), it was found that the concentrations at the sampling times provided a good approximation of the time description of the concentration graph. As a result, an integration using the same integration techniques but only those concentrations at sample times, i.e., actual data, were compared with the more detailed interpolating integration method. A sample hydrograph is shown in Figure 2 to demonstrate typical sampling frequency and the analyses made on each sample. From the results shown in Table 2, it was concluded that the two methods provided very similar discharge quantities and average concentrations, thus the actual data concentrations were integrated throughout the study data.

TYPING GUIDE SHEET

TABLE 2. COMPARISON OF ACTUAL DATA AND INTERPOLATED DATA POINT INTEGRATIONS DURING OCTOBER-DECEMBER, 1977, ROCK CREEK MAIN WATERSHED

Parameter	Actual data Quantity	 Avg. conc.	Interpolated data Quantity	 Avg. conc.
	(kg)	(mg/l)	(kg)	(mg/l)
NO_3^--N	2.5	0.34	2.4	0.33
NH_4^+-N	0.2	0.03	0.2	0.03
Soluble Org.-N	8.3	1.1	7.4	1.0
Soluble TKN	8.5	1.2	9.5	1.3
Soluble Total-N	11.1	1.5	10.6	1.4
Total Org.-N	53.2	7.2	50.4	6.8
TKN	53.5	7.3	50.4	6.8
Total-N	56.0	7.5	59.5	8.1
Sediment N	44.8	6.1	41.4	3.6
Ortho-PO_4^{-3}	1.8	0.25	1.8	0.25
Soluble Org.-P	0.5	0.07	0.5	0.06
Soluble Total-P	2.6	0.36	2.4	0.33
Total Org.-P	43.9	5.9	11.1	1.5
Total-P	21.5	2.9	22.4	3.0
Sediment P	18.9	2.6	22.0	3.0
TOC	115.0	15.5	115.0	15.6
COD	427.0	58.0	417.0	57.0
BOD	14.0	1.9	14.0	1.9
Cl^-	3.9	0.52	4.1	0.56
Na	33.9	4.6	34.6	4.7
Ca	26.8	3.6	24.9	3.4
Mg	8.9	1.2	9.2	1.3
K	23.4	3.2	22.8	3.1

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

SECTION 7

RESULTS AND DISCUSSION

HYDROLOGY AND SEDIMENT

To adequately research the water quality emanating from a given watershed, considerable effort must be included toward measuring and defining the causative hydrology of the study watershed if the results are to be fully interpreted, put into perspective compared to long time expected climate, and appropriately transferred to other sites having different characteristics. As a result, continuous measurements were obtained for the principle hydrologic components of precipitation, streamflow at the gaging sites, and climatic variables. Frequent sampling of other hydrologic components such as soil moisture, groundwater levels, and pan evaporation provided an intensive scenario of the watershed hydrology during the study period.

Sediment is the most common, and often the most degrading, water quality parameter. It is very closely allied with surface hydrology through land use and surface runoff, and as such, it is common to consider sediment and hydrology together. However, in a study such as this, where water quality is the major emphasis, sediment plays an extended role because many of the chemical and biological water quality parameters are transported by and are an integral part of the sediment.

Daily quantitities of precipitation, streamflow, and sediment measured on the main and check watersheds are tablulated in Appendix A. Each of these daily values is the integral of the measured rates of precipitation and discharge which were tabulated on very short time intervals depending upon the rate of change. Examples of these detailed values will be given, but their large volume precludes publishing more than the daily and longer period accumulations. A brief discussion of each major data set follows to provide more specific examples and interpretation.

Precipitation

For the three study years, precipitation ranged from near drought during the 1976-77 winter to above normal for 1977-78, and near normal for 1978-79. The monthly values for these years are shown in Figure 3, along with the normal amount based on a 30-year record at Potlatch, Idaho (6.4 Km due north and 120 m less elevation). Normal precipitation at the study site would likely be nearly equal to that at Potlatch, ID.

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Daily accumulative precipitation is presented in Figure 4, which clearly shows the three years with respect to normal and each other. Data from the Potlatch gage were substituted for the period prior to the beginning of data taking at the site in December 1976. Table 3 provides a monthly summary of precipitation measured by each gage and the nearby weather bureau gages at Potlatch and Moscow, ID. It was noted early in the study that low intensity precipitation falling into the propane heated tipping bucket gages registered significantly less than the adjacent gages because of evaporation from the heated gage bucket. As a result, these tipping bucket data were inaccurate during winter months when the heater was used and were, therefore, omitted.

Precipitation during the three study years averaged 65 mm (2.6 in) below the Potlatch normal of 622 mm (24.5 in). The first year was a severe regional drought with very limited snow cover at any time and only 370 mm (14.6 in) on the watershed. The two subsequent years were more nearly normal, but neither of these years had a large snowpack accumulation because of mid-winter thaws. February 1979 had the largest accumulation of snow depth (about 45 cm) as shown in Figures 5, 6 and 7, and this melt provided the largest surface runoff measured during the study. Discussions with local ranchers indicated that normal accumulative snow depths would be slightly greater than any that were measured.

The precipitation features that are most influential to runoff water quality are that: (a) very little precipitation, and essentially no runoff, occurs in the summer grazing period, (b) the rain and snow are almost always very low intensity, and (c) a significant amount of the precipitation is snow which may form a significant snowpack depending on the precipitation regime and location elevation. As discussed later, there is a significant difference between water quality from rain on wet or frozen soil and snowmelt water from beneath a snowpack. Thus the form, distribution, and intensity all play significant roles in the amount of surface runoff and its resultant quality.

Streamflow

Observed streamflow from the study watersheds followed the precipitation trends very closely. The 1976-77 winter had far below expected runoff amounts, while the two subsequent study years had more normal amounts. The study period provided a wide variety of flow events in different sequences which make the average results applicable to other situations.

Annual observed streamflow amounts are given in Table 4 for the check and main watersheds. The flow is expressed in total volume (m^3) plus equivalent flow depths from the watershed area (mm). Peak flows are by actual flow rate and are not corrected for contributing area.

The main watershed measuring weir intercepted seepage flow from the saturated perched water tables and a small baseflow (seepage flow; groundwater discharge) occurred during most spring months. An estimate was made of the amount of the total flow that was generated as surface runoff by estimating the daily baseflow rate during days which had surface runoff. These surface values are given in Table 4, and the monthly estimates are in Appendix A. The check watershed had very little seepage flow, thus the total flow is assumed to be surface runoff. For this study, the surface runoff is the most important component because it is most likely to be affected by the grazing operation.

Figures 5, 6, and 7 provide a daily summary of the precipitation, runoff, snow depths, and snow cover during the winter season when nearly all runoff occurred. These figures graphically show the features of the three gaged seasons. The drought year, 1976-77, had few runoff days; 1977-78 had several periods of snow accumulation and melt; and 1978-79 developed a moderate snowpack which melted in a few days during early February. These amounts and patterns are important to the water quality interpretations because the melt rates, time of bare surface, and whether there is snow present when runoff occurs will all likely impact the amount of flushing action as the water flows over the pasture surface and thus will influence the amount of sediment, manure, chemicals, and bacteria transported in the streamflow.

A summary of total runoff during days when significant surface runoff occurred is given in Table 5 for the complete study period. It is difficult to associate causative precipitation with each event because most events include some melt of snow which occurred over various preceding periods. Rain often is associated with the snowmelt period.

It is obvious from each of these event, daily, monthly, and annual summaries that the check watershed had significantly less runoff than the main watershed. The one exception was the frozen ground runoff events in 1976-77. This is not unexpected because the check watershed was situated on an upland area with less steep topography and no wet bottomland. These differences are always a problem in paired watershed studies, and especially so when the topography, geologic setting, and total areas differ considerably. The surface runoff of the check area was only 40 and 30 percent of the main watershed for the 1977-78 and 1978-79 seasons (Table 4 values). Little or no runoff was observed from its south side except in frozen conditions. The effect of these differences on the water quality interpretations is likely not so severe because the check area did have sufficient runoff these two years to provide significant surface flushing and numerous sampling opportunities to contrast simultaneously with those from the main watershed.

Sediment

Daily measured sediment values are given in Appendix A and the annual amounts in several different units in Table 6. These quantities were developed by detailed integrations of numerous sediment sample concentrations during each flow event with the corresponding flow rates. Runoff hydrographs and sediment concentrations were graphed for each period of surface flow. All anamolies were reviewed before numerical integrations were made to determine event and daily discharges. Example graphs for the check and main are shown in Figures 8 and 9, respectively.

TYPING GUIDE SHEET

Sediment concentrations and total quantities were quite low for both watersheds when compared with any other agriculturally used areas. The average concentrations for all three years from the main watershed was 424 milligrams/liter (mg/l) (Table 6), with the maximum sample having 12,700 mg/l and minimum sample having one mg/l (during baseflow). Average sediment yield was 382 kg/ha. These values compare with mean concentrations and yield of 7,400 mg/l and 5,900 kg/ha, respectively, from wheat land in our region (Missouri Flat Creek, 70 km^2, 1961-1965), thus the grassed pasture area is more than a full magnitude less than that delivered from a much larger farmed watershed.

The check watershed had significantly less sediment discharge of only 19 kg/ha corresponding with the much less total streamflow, but the mean concentrations were also only 10 to 20 percent of those from the main watershed. The maximum sampled concentration was 2,105 mg/l. The much lower concentrations and yields may partially be influenced by the topographic setting, but the observations indicate that much of this difference is attributed to the presence of cattle on the main watershed. Many cattle trails were developed throughout the main watershed and they were especially concentrated in the spring and channel area where watering occurred. Several trails in this mid-watershed area intercepted the surface runoff and became the controlling channels. They eroded significantly (5 to 10 cm in depth) and this sediment went directly into the small streams.

The stream immediately above the main gaging location had small 15 to 30 cm banks that were largely unprotected by vegetation. Through watering and grazing the cattle added some disturbance to this area which added to the natural tendency for this small channel to erode. The upland channel directly west of the weather station also had some exposed banks and a small overfall which eroded some during the study. Again, there was some cattle activity in this channel which undoubtedly aggravated the erosion. Beyond the trails and channels there was little visible erosion. These upland grass areas probably produced amounts similar to those measured on the check watershed where there were no apparent areas exposed from good grass vegetation.

Climatic Data

Basic climatic data were obtained throughout the study period to document the existing conditions and aid in present and future interpretations. These data are supplied in Appendix B. Included are daily maximum-minimum air temperature, daily pan evaporation during summer months, and daily wind travel 30 cm above the soil surface at the edge of the evaporation pan. Numerous other data such as soil temperatures, soil frost depths, wind travel and direction at 3 m, and solar radiation were obtained but are not included in this report.

Soil Moisture

Soil moisture was measured at the nine sites shown in Figure 1 on 28 dates during the study period. Frequency was about once each month with

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

more readings during the growing season than in winter. Neutron probe values were taken at 15 cm increments to 165 or 180 cm, plus gravimetric samples taken 0 to 7, 7 to 15, 15 to 30, and 30 to 45 cm to define the surface condition. All values were converted to percent by volume.

The depth distributions shown in Figure 10 for selected dates of a mid-watershed site (No. 5) show the typical annual progression of soil moisture. Spring is a recharge period by snowmelt and rain such that the complete profile is at or above field capacity. With grass growth, increased evaporative demand, reduced precipitation, and perhaps some deep percolation, the soil moisture decreases rapidly throughout the summer months. Wilting point is often approached by August in the upper layers. These data also show that little water withdrawal occurs below 75 cm (30 in.) by the predominantly shallow rooted grass.

Soil moisture relates to water quality through secondary processes. It is a prime determinant of runoff volume and soil temperature, biologic activity depending on soil moisture status, and grass growth and surface residues controlled by soil moisture. These relationships must be kept in mind when interpreting the hydrologic and water quality characteristics.

Groundwater

The level of water in two-inch diameter wells in and adjacent to the stream alluvium were measured routinely during the study. These are shown graphically in Figures 11, 12, and 13 for the three study years as depths from the soil surface at the well site. Primarily, these groundwater levels demonstrate the period of recharge by winter precipitation and drainout by stream baseflow and evapotranspiration. No attempt has yet been made to analyze gradients or more detailed porus media flow phenomena which occurred. Without more detailed geologic investigation, this could probably not be accomplished.

As with soil moisture, the groundwater has only an indirect effect on discharged water quality. It does provide continuous seepage flow in the lower 50 m of the main watershed channel which may have provided favorable conditions for biologic activity not possible on the check watershed. More directly, it did provide cattle water along the main channel which caused a concentration of manure and trampling.

Water Temperature and Dissolved Oxygen

Temperature and dissolved oxygen (DO) are two basic water quality parameters which may influence other water biologic activity. These were measured manually during watershed inspections when streamflow was present and are shown in Figures 14 and 15 for the check and main watersheds.

The annual variation of water temperature is apparent and the DO levels were nearly always above 90 percent of saturation when flow was occurring. The direct or indirect efforts on chemical and biologic water quality parameters is not readily apparent. The range of these values does document

EPA-287 (Cin.)
(4-76)

that this is a cold stream during most of the discharge period with high levels of DO. Combining these data with streamflow rates, BOD, and COD data will further provide the general water quality status of this stream.

Manure Distribution

To provide direct measurements of the manure distribution on the main watershed, counts were made three different dates during 1978 at early summer, midsummer, and just after cattle were removed. The watershed was stratified into three sampling zones of (a) high cattle use due to loafing or watering, (b) along drainages, and (c) general grazing. Eight sample sites were made in zone (a), 10 along the waterways, and 20 randomly placed throughout the watershed. Each sample consisted of counting the number of manure drops in a 50 m^2 area and sampling the weight and size of the droppings. The high use areas were difficult to count due to trampling of the droppings.

Results of the fecal sampling are shown in Table 7. As can be seen, the fecal deposits were not evenly distributed over the watershed, but were concentrated in high-use areas and, to some extent, along drainages. The high drainage density was probably due to the location of some animal trails in the pasture. The situation is compounded when it is considered that two of the high-use sites were in or immediately adjacent to drainage bottoms.

On an overall basis, the density of fecal deposits across the entire watershed was 2,645 deposits/ha, providing a coverage of 1.45 percent. Therefore, if the distribution of droppings were more uniform, the concentrations in the drainages would have approached that which was present elsewhere in the nonconcentrated areas. In the opinion of the researchers, one must suspect that the fecal bacteria counts in the runoff are a result of the distribution of feces much more than the overall fecal density. This is one subject which should be seriously considered for additional research.

WATER CHEMICALS AND OXYGEN

During the drouth water-year (1977), N and P losses in runoff from the main and check watersheds were insignificant (Tables 8 and 9). While it may appear that N and P losses are somewhat different for the main and check watersheds, both watersheds were grazed the summer and fall of 1976, the year of study initiation, so differences in losses can only be attributed to hydrological differences between the two watersheds.

In water-year 1978, total N loss was only 3.8 and 0.48 kg/ha from the main and check watersheds, respectively, which was more than during 1977 but was still low (Tables 10 and 11). Nitrate concentrations were almost negligible with a total loss of only 0.33 and .08 kg/ha NO_3-N, respectively. N parameters were higher from the main watershed than the check, but no parameters were of sufficient magnitude to be of environmental concern. N concentrations were high in runoff when the pond was drained and in the initial runoff samples in the fall after the summer grazing season. These higher concentrations probably resulted from relatively fresh manure particles being carried in the runoff from the pasture and within the main stream channel. The pond was fenced to exclude cattle but they did have access to the main channel below the pond to the sampling site. Throughout this study, the periods of greatest nutrient concentrations were associated with small runoff volumes such as early season events, summer events, or pond drainage. Thus, these events contributed very little to the annual constituent discharge. Average concentrations of N in the baseflow was about one-half that of the surface runoff.

While NO_3-N losses in runoff from the main watershed were slightly greater in water-year 1979 than in 1978 (1.33 kg/ha vs. 0.33 kg/ha), most N losses in runoff were less in 1979 (Tables 12 and 13), thus total N losses were similar. Again, N losses in runoff were low and were generally lower than would be expected in runoff from areas used for other agricultural purposes. Total N losses were greater from the main watershed than the check watershed. Exchangeable sediment NH_4^+ was not run during water-year 1979 because it was negligible during water-year 1978.

P deliveries from both watersheds were negligible during water-year 1977 (Tables 8 and 9). P deliveries in runoff were very low for water-year 1978 with runoff from the grazed area delivering only 0.2 kg/ha/yr ortho-P with a total-P loss of only 1.27 kg/ha/yr (Tables 14 and 15). While these deliveries are about 10 times more than from the check area, they are low. The pond draining event on November 9 caused elevated P levels, probably due to channel scour, but this was an artificially induced flow and not related to natural streamflow. P levels in the runoff did increase when cattle were present during the July 4 event; however, this was a very small event and may not have reflected the true picture. Obviously the presence of cattle will raise P levels in runoff, but this event would not be expected to be representative. In any case, even with these high concentrations, the annual discharge was negligible due to small streamflows during these times. Very small amounts of P were delivered by baseflow even though baseflow was about one-third of the total water lost during the 1978 water year.

In water-year 1979, P deliveries in runoff and baseflow were low from the main and check watersheds (Tables 16 and 17). Generally, average ortho-P concentrations in runoff from the main watershed were higher in water-year 1979 than in 1978; in both years ortho-P in runoff decreased as the length of time animals were off the pasture increased. Total-P lost in runoff from the grazed watershed was slightly greater in water-year 1978 (1.27 kg/ha) than in water-year 1979 (0.93 kg/ha). If baseflow was added, the values were 1.39 and 1.05 kg/ha, respectively. The greater total-P loss in water-year 1978 was likely due to the December 10-15, 1977 event that had a high average total-P concentration of 3.12 mg/l. Ortho-P and total-P losses from the check watershed during water-year 1979 were 0.02 and 0.07 kg/ha, respectively.

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

The oxygen demand, pH, SC, Cl^-, and cation delivery for the main and check watersheds for water-years 1977, 1978, and 1979 are summarized in Tables D-1 through D-6 in Appendix D. During the establishment year, water-year 1977, oxygen demand for the main watershed was about twice that of the check (probably due to stagnation); pH for the main watershed appeared slightly more alkaline than the check, the SC of the main watershed was somewhat greater than the check watershed, as was Cl^- and cation delivery. The oxygen demand of the runoff from the grazed watershed was about three times that of the ungrazed watershed during water-year 1978 while Cl^- and cations were about five times greater. Values for these parameters increased in runoff from the main watershed when cattle were present (July 4 event). Oxygen demand of runoff in water-year 1979 was greater from the grazed area than in 1978, but runoff from the ungrazed area was similar (Tables D-5 and D-6). Cations were not run during water-year 1979 because data from the previous year had shown that SC was well correlated with the Na, K, Ca, and Mg present in the runoff.

Precipitation N, Groundwater Quality, and Profile Constituents

For water-year 1977, precipitation delivered 0.94 kg/ha NO_3^--N and 2.37 kg/ha NH_4^+-N. Because of the drouth, insufficient sample volumes were available to assess total-N delivery by precipitation. During water-year 1978, precipitation delivered 2.19 kg/ha NO_3^--N, 1.86 kg/ha NH_4^+-N, and 4.31 kg/ha T-N. In water-year 1979, 1.1 kg/ha NO_3^--N, 1.96 kg/ha NH_4^+-N, and 3.48 kg/ha T-N were received on the area in precipitation. N delivered to the watershed area by precipitation was greater than the quantities of N leaving the watershed with the runoff from the grazed area for water-years 1977 and 1978, and only slightly less for 1979.

Groundwater quality under the grazed watershed was sampled periodically during the three-year study. All samples obtained showed good water quality, for example NO_3^--N content was always low and usually did not exceed 1 ppm. Other parameters were of similar magnitude. N and exchangeable P in the soil profile did not show any concentrations that would be considered environmentally unacceptable and during the study did not increase in soil samples from the areas tested.

INDICATOR BACTERIA

TC counts in runoff showed little relationship to the presence or absence of cattle as shown by the main and check watershed result summaries presented in Tables 18, 19, 20, 21, 22, and 23. TC counts probably responded more to climate than to the cattle as shown by the check watershed results (Tables 19, 21, and 23). The reader must recall that there was no treatment difference between the main and check watershed for water-year 1977. From results of this study, TC counts appear to be useless for determining stream pollution.

EPA-287 (Cin.)
(4-76)

In general, the FC and FS numbers decreased as expected throughout the winter months. Their numbers, however, unexpectedly increased again in the spring with warmer weather (see Tables 20-23). Also, the FC/FS ratios varied more than expected, ranging from as high as 4/1 on the check watershed to 1/1 on the main watershed (see Tables 18-23).

FC/FS ratios of about 0.1 to 1.0 indicate cattle fecal contamination. Runoff contaminated with cattle normally has a FC/FS ratio of about 0.7 while that with human had a FC/FS ratio of 4.0 and higher. Animal FC/FS ratios will increase with time (Geldreich, 1976), but they should remain less than one. The high FC/FS ratios long after cattle were removed from the area would lead one to question the validity of the FC/FS ratio for nonpoint areas. Doran and Linn (1979) have also questioned use of the FC/FS ratio for this purpose. Furthermore, when animals were introduced back onto the watershed, the June 4, 1977 readings showed high FC and FS numbers but a FC/FS ratio of 0.02, which is indicative of wild animal fecal contamination (Geldreich, 1976). During the three-year study period, except for a few mice and squirrels, wildlife populations on the study areas were almost nil.

In 1977, average FC numbers exceeded recommended primary contact numbers for six out of 11 events for the main watershed and met or exceeded these recommendations two out of four events on the check watershed (See Table 24). The apparent increase of numbers of FC and FS bacteria in runoff during April and later in the prolonged absence of cattle and of appreciable numbers of wildlife was surprising. Furthermore, the FC/FS ratios indicate livestock were the fecal source. The same bacterial pattern occurred in water-year 1978 on the main watershed (Table 20), while on the check watershed FS and possibly FC numbers increased in the spring (Table 21). However, the FC/FS ratios on the check watershed for the April and May events were not indicative of cattle fecal pollution. Geldreich (1976) cites several examples which showed that FS can be indigenous to vegetation; however, at least on the main watershed it appears that both FC and FS multiplied in the spring correlating with a period of warm, dry weather followed by wet weather. During water-year 1978, the cattle were just removed when the October 30, 1977 event occurred with high numbers of FC and FS in runoff from the main watershed with a FC/FS ratio indicative of cattle fecal pollution. Surprisingly, the later November 8, 1977 event gave even higher numbers of FC and FS in the runoff, but the FC/FS ratio was lower than the October 30 event. These data are surprising because for a time after manure deposition FC/FS ratios should increase because of rapid dieoff of *S. bovis* and *S. equinus*; just the opposite situation existed here--both FC and FS increased. No convenient explanations are evident. As the water-year continued, FC and FS numbers decreased on both watersheds to below maximum recommended primary contact numbers; but again coincident with warm, wet weather in the spring, they increased in the runoff from both watersheds. FC/FS ratios were indicative of wild animal pollution on the check watershed during some events but not others. The data from the check watershed for water-year 1978 indicate FC/FS ratios are not useful for assessing nonpoint fecal pollution sources and data from the main watershed indicate the same. FC are normally considered a good measure of recent fecal pollution but from an average of 40 FC/100 ml of runoff for the

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

March 12-15 event they increased to 5400 FC/100 ml of runoff in the May 15-16 event in the absence of animals on the main watershed and from an average of 10 FC/100 ml to 160 FC/100 ml for the same events on the check watershed. These data cause the researchers to question the validity of using FC, FS or FC/FS ratios for assessing recent cattle fecal pollution from a nonpoint source such as grazing animals. During the July 4, 1978 event when animals were on the pasture, the FC and FS were much higher in the runoff than at any time when animals were absent.

In water-year 1979, FC and FS numbers in runoff from the main watershed and FC/FS ratios behaved similarly to those trends shown during water-year 1978 (Table 22). During water-year 1979, cattle were removed from the watershed before any runoff event; however, the animals had been off the watershed only four days before the November 14 event which obviously provided the high average numbers of FC and FS observed. FC and FS numbers were again elevated during the May 4-9, 1979 event, long after cattle were removed in October, 1978, but warm spring weather had occurred just before the event.

By water-year 1979, FC for all events from the check watershed were low and FC/FS ratios were very low (Table 23). However, almost three years were required to establish this low level of FC on the check watershed. These data indicate that present bacterial standards (Table 24) are inadequate for assessing the bacterial pollution potential from nonpoint cattle grazed areas.

The effect of grazing cattle on runoff water quality from the study watersheds can be summarized by the following. TC in runoff, as others have found, had an apparent relationship to cattle grazing operations, but numbers were elevated when they should not have been. FC and FS numbers in runoff from the grazed watershed were elevated when cattle were on the pasture. After cattle were removed, FC and FS numbers generally declined throughout the fall and winter months. However, after several months absence of cattle from the area, FC and FS numbers in runoff from the grazed watershed were elevated and in many cases exceeded suggested water quality standards. FC and FS numbers appeared to increase in runoff from the grazed area in the spring in rainfall runoff following a period of warm, dry weather several months after animals were removed. FC/FS ratios in runoff varied considerably and indicated recent cattle fecal pollution for long periods of time after animals were off the grazed area. FS numbers in runoff from the grazed and check areas did not change appreciably during the study. The check was ungrazed from the fall of 1976 throughout the study. FC numbers in runoff from the check were not consistently below the maximum recommended numbers for primary contact until the 1979 water-year, although FC numbers in the check watershed runoff during water-year 1978 were generally below or close to the recommended primary contact standard. The data would suggest using conventional FC/FS ratios or FC numbers in runoff as a measurement of recent fecal pollution by cattle on a grazed area are of limited value in the Pacific Northwest.

PARAMETER RESPONSE AND SPATIAL DISTRIBUTION

Parameter Response

The type of runoff event affected the parameter response to streamflow (Table 25). A typical parameter direct response to streamflow during rainfall runoff is shown for FC and FS in Figure 16. A typical inverse response of the parameter SC to rainfall runoff is shown in Figure 17. With snowmelt on thawed ground followed by rain, NO_3-N does not follow the hydrograph initially during snowmelt (Figure 18); however, when the ground thawed, NO_3 concentration increased. Ortho P did not follow the hydrograph at any time during a snowfall-rain on frozen soil event (Figure 19). For the same event, COD also did not appear to respond to streamflow until the ground began to thaw on the second day of the event (Figure 20). Total P is a good example of the pattern seen during a mixed snowmelt rainfall event (Figure 21). The water quality parameter, in this case total-P, did not respond to the streamflow increase caused by snowmelt, but did respond to the later streamflow increase caused by rainfall runoff. During long and large events, the check watershed behaved similarly. The highest check watershed values often occurred in the first few runoff samples as the check watershed channel was flushed since it had no base flow. For small events, parameter concentrations for check runoff therefore did not correlate well with flow rates.

Spatial Distribution

Hand samples were collected from various locations within the watershed during events in the 1978 and 1979 water-years to determine the effect of grazing patterns, manure density and land cover on water quality parameter concentrations. Of specific interest was whether the pollution load was primarily a result of cattle activity in and immediately adjacent to the stream channel (the "sacrifice area" between the north and south pastures) or if the stream water quality reflected the grazing activity over the entire watershed. The sampling site locations are shown in Figure 22.

During the 1978 water-year, samples were taken December 6, 1977 during a small snowmelt/rainfall event; December 13, 1977, during the largest event of the water-year; and on March 15, 1977, during a late winter medium sized rainfall event. In water-year 1979 samples were taken from an event caused primarily by snowmelt on February 13, 1979 during the largest event of the water-year and of the entire study; February 27, 1979 during a large rainfall/ snowmelt event; April 6, 1979, during an early spring rainfall event and on May 4, 1979 at the beginning of a large spring rainfall event. This last sampling occurred after indicator bacterial numbers had increased above their late winter values.

Fecal density and distribution data were collected during the study by the range management component of the project (see Section VI of the Range Management Section). The amount of a drainage area within the pastured watershed covered by feces varied from 20 percent for site 1 (sacrifice pasture) to 0.7 percent for site 12 (northeast area) at the November 7, 1978 sampling date (Table 26). The percent manure cover was determined three times during the summer of 1978. The values obtained on Nov. 7, 1978 after the cattle were removed from the watershed represent the fecal densities present when these water quality samples were taken from the 1979 water year runoff. FC and FS numbers in runoff from the various sampling sites within the watershed did not correlate clearly with fecal deposition in water-year 1978 or 1979 (Table 27). In fact, no trends are apparent from the sites sampled. Also, N and P in the runoff from the various sampling sites within the pastured watershed did not appear to agree with manure deposition (Table 28). Presumably vegetation and soil cover had a greater effect on runoff nutrient content than did manure deposition.

These results would indicate that indicator bacteria and nutrients in runoff from the main pasture areas were generally equal to those at the main sampling station. The pollution load can be considered non-point source in origin and not primarily a result of the greater grazing activity in the sacrifice area.

TABLE 3. MONTHLY PRECIPITATION DATA SUMMARY, ROCK CREEK WATERSHED, 1977, 1978, AND 1979 WATER YEARS

Site	YR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
		(milimeters)												
Main storage	77	--	--	--	--	--	20.4*	8.7	67.8	17.2	19.7	68.2	48.3	250.8*
	78	33.8	79.9	127.3	64.0	66.0	43.0	75.0	53.2	18.6	21.1	52.7	28.5	663.1
	79	2.2	56.6	76.0	41.0	125.0	48.0	71.5	50.3	23.4	12.0*	--	--	506.0*
Main† tipping	77	--	--	--	--	--	--	--	70.1	17.0	18.5	65.5	44.7	--
	78	--	--	--	--	--	--	--	40.9*	18.3	25.1	51.8	27.2	--
	79	--	--	--	--	--	--	--	17.8*	20.3	8.9*	--	--	--
Check storage	77	--	12.2*	33.8	20.1	18.3	50.1	8.7	74.4	18.7	21.4	70.6	51.4	380.0*
	78	37.3	81.1	137.6	63.0	69.0	45.0	81.0	54.0	20.0	28.0	53.0	31.0	700.0
	79	1.0	58.0	74.0	43.0	135.0	48.0	74.0	49.0	25.0	13.0*	--	--	520.0*
Check† tipping	77	--	--	--	--	--	--	--	71.6	17.0	18.0	66.0	47.2	--
	78	--	--	--	--	--	--	--	51.1	19.3	24.9	49.3	26.2	--
	79	--	--	--	--	--	--	--	--	18.0*	8.6*	--	--	--
Weighing	77	--	--	20.0*	21.0	19.5	57.0	9.5	67.0	17.5	17.5	64.0	47.0	340.0*
	78	31.0	78.5	143.5	66.5	67.0	40.0	73.0	50.0	18.0	26.0	53.0	29.5	676.0
	79	2.0	66.5	79.0	56.0	123.0	50.5	65.5	46.5	24.0	10.0*	--	--	523.0*
Watershed‡	77	--	12.2*	33.8	20.6	18.9	53.6	9.0	70.2	17.5	19.0	66.9	47.8	369.5*
	78	34.0	79.8	136.1	64.5	67.3	42.7	76.3	52.1	18.8	25.0	52.0	27.9	676.5
	79	1.8	60.4	76.3	46.7	127.6	48.8	70.3	48.6	24.1	11.7*	--	--	516.3*

(continued)

TABLE 3 (continued)

Site	YR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Moscow	77	58.7	23.6	30.7	19.6	19.3	42.4	11.9	72.6	15.0	17.0	72.6	63.8	447.2
	78	27.7	99.1	119.6	77.2	58.4	41.4	120.4	56.9	23.6	26.7	53.6	39.4	744.0
	79	2.3	48.8	64.0	27.2	104.6	52.3	83.8	71.6	25.7	12.4	25.1	10.4	528.2
	Normal	49.5	73.2	76.7	74.2	52.3	46.5	46.2	46.2	45.5	14.5	17.8	32.0	574.6
Potlatch	77	37.1	17.0	39.6	27.2	29.7	45.7	9.9	69.6	19.6	19.3	45.0	49.3	409.0
	78	36.3	84.6	153.7	77.5	56.4	35.3	107.2	49.5	23.9	42.2	55.6	36.6	758.8
	79	1.5	63.8	67.6	47.2	124.2	62.2	59.7	50.0	25.4	17.3	50.8	12.2	581.9
	Normal	53.8	73.2	82.3	79.2	58.2	51.3	47.8	50.0	55.6	17.3	18.3	35.1	622.1

* Value represents only part of month or year.

† Data from tipping bucket gages omitted during periods of heating because gages evaporated the precipitation and significantly under-recorded.

‡ The watershed value is an average between the storage and weighing gage values (where full month data available) during October through April and the average of all the gages during May through September.

TABLE 4. ANNUAL STREAMFLOW SUMMARY

	1977*		1978		1979†	
	Main	Check	Main	Check	Main	Check
Precipitation, mm	370		676		516	
Runoff						
Volume, m^3	2,451	308	38,193	422	40,623	370
Depth, mm						
Total Flow	11	34	178	46	189	41
Surface Flow	10	34	119	46	136	41
Peak flow, l/sec	26	4	103	4	145	3

* Measurements Nov. 4, 1976 to Sep. 30, 1977

† Measurements Oct. 1, 1978 to July 5, 1979

TABLE 5. RUNOFF EVENT SUMMARY

Event dates	Main watershed Peak l/sec	Main watershed Volume m^3	Main watershed Volume mm*	Check watershed Peak l/sec	Check watershed Volume m^3	Check watershed Volume mm*	Event type
1977							
Dec. 26-27, 1976	3.6	161.0	0.7	1.5	82.9	9.1	Snowmelt/rain on frozen ground
Jan. 16-19, 1977	26.4	1,775.0	8.3	3.9	203.7	22.5	Snowmelt/rain on frozen ground
Feb. 8-10	1.6	94.5	0.4	0.4	0.0	1.3	Rain/snowmelt
Feb. 28-Mar. 1	0.6	25.4	0.1	0.0	0.0	0.0	Rain on snow
Mar. 7-10	1.2	65.4	0.3	-	-	-	Rain and snow
Mar 7-9	-	-	-	0.2	2.8	0.3	Rain and snow
Mar. 15-20	0.5	51.9	0.2	-	-	-	Snowmelt and rain
Mar. 19	-	-	-	0.0	0.0	0.0	Snowmelt and rain
Mar. 27-28	0.6	15.8	0.1	-	-	-	Snow and rain
Mar. 27	-	-	-	0.0	0.0	0.0	Snow and rain
Apr. 13-14	0.5	4.9	0.0	0.0	0.0	0.0	Rain
May 2-4	0.1	3.6	0.0	0.0	0.0	0.0	Rain
May 17-18	0.2	11.8	0.0	0.0	0.0	0.0	Rain
May 26-27	0.4	3.7	0.0	0.0	0.0	0.0	Rain
June 4	0.0	0.2	0.0	0.0	0.0	0.0	Rain
Nov. 8	38.6	23.0	0.1	-	-	-	Draining water pond
Nov. 25-29	13.4	302.0	1.4	0.7	15.0	1.6	Snowmelt and rain
Dec. 1-3	4.4	162.0	0.8	0.6	15.3	1.7	Snowmelt and rain
Dec. 6-7	4.0	107.0	0.5	0.2	4.0	0.4	Snowmelt and rain
Dec. 10-11	46.4	1,223.0	5.7	1.6	35.9	4.0	Snowmelt and rain
Dec. 13	102.9	2,589.0	12.0	3.2	56.7	6.3	Rain
Dec. 14	82.8	1,541.0	7.2	3.5	27.7	3.1	Rain
Dec. 15	42.1	1,077.0	5.0	2.0	18.8	2.1	Rain

(continued)

TABLE 5 (continued)

Event dates	Main watershed			Check watershed			Event type
	Peak	Volume		Peak	Volume		
	l/sec	m^3	mm	l/sec	m^3	mm	
1978							
Jan. 5-6	30.8	2,916.0	13.6	0.6	53.1	5.9	Snowmelt and rain
Jan. 8-9	32.3	2,420.0	11.3	0.7	33.8	3.7	Rain and snowmelt
Jan. 15-16	12.8	827.0	3.8	0.2	4.8	0.5	Rain and limited snowmelt
Feb. 2-4	42.7	2,762.0	12.8	1.2	40.7	4.5	Snowmelt and some rain
Feb. 5-6	46.4	2,493.0	11.6	1.1	19.6	2.1	Rain
Feb. 7	60.0	1,602.0	7.5	1.7	21.2	2.3	Rain
Feb. 24 - Mar. 5	7.2	2,240.0	10.4	0.1	9.4	1.0	Snowmelt and rain
Mar. 7-9	13.4	1,238.0	5.8	0.3	9.6	1.0	Rain
Mar. 12-15	10.7	1,152.0	5.4	0.2	5.6	0.6	Snowmelt
Apr. 1-2	9.1	642.0	3.0	0.6	14.2	1.6	Rain
Apr. 4-5	4.8	283.0	1.3	0.1	2.1	0.2	Rain
Apr. 7	12.5	391.0	1.8	0.5	7.3	0.8	Snow and rain
Apr. 16	4.1	123.0	0.6	0.2	2.5	0.3	Rain and snow
Apr. 27-28	1.2	166.0	0.8	0.1	4.2	0.5	Rain
May 15-17	9.1	149.0	0.7	1.1	5.8	0.6	Rain
May 21	1.1	11.0	0.1	-	-	-	Rain (intense)
Nov. 4	0.1	0.9	0.0	-	-	-	Rain
Nov. 17	0.3	6.0	0.0	-	-	-	Rain
Dec. 3-4	1.0	47.3	0.2	0.3	10.1	1.1	Snowmelt
Dec. 11	2.7	96.7	0.4	0.6	18.9	2.1	Rain on snow
Dec. 23-24	1.1	68.3	0.3	0.3	11.0	1.2	Snowmelt

(continued)

TABLE 5 (continued)

Event dates	Main watershed			Check watershed			Event type
	Peak	Volume		Peak	Volume		
	l/sec	m^3	mm	l/sec	m^3	mm	
1979							
Feb. 6-7	1.1	50.4	0.2	0.1	3.0	0.3	Rain on snow
Feb. 9-14	145.1	12,523.3	58.2	1.9	169.4	18.7	Rain on snow
Feb. 17-20	9.1	1,487.1	6.9	0.2	12.1	1.3	Snowmelt and rain
Feb. 24-28	37.0	5,142.7	23.9	0.8	42.3	4.7	Rain on snow
Mar. 4-7	23.2	4,459.0	20.7	0.2	15.8	1.7	Rain
Mar. 15-16	8.2	650.7	3.0	0.1	1.7	0.2	Rain
Mar. 27-28	11.2	532.2	2.5	0.4	6.4	0.7	Rain
Apr. 2-4	13.4	1,001.4	4.7	0.3	4.7	0.5	Snowmelt
Apr. 6	28.4	834.9	3.9	0.9	11.8	1.3	Rain
Apr. 8-9	16.5	875.9	4.1	0.3	3.1	0.3	Rain
Apr. 13-14	40.4	675.5	3.1	1.1	4.1	0.5	Rain
Apr. 16-17	21.6	631.8	2.9	0.4	3.9	0.4	Rain
Apr. 23-24	14.0	623.4	2.9	0.5	6.7	0.7	Rain
May 4-6	51.6	3,079.6	14.3	3.0	43.8	4.8	Rain
May 8-9	7.6	4[illegible].4	2.1	-	-	-	Rain

* Expressed as depth from contributing area.

TABLE 6. ANNUAL SEDIMENT SUMMARY

	1977*		1978		1979†		3-yr avg	
	Main	Check	Main	Check	Main	Check	Main	Check
Precipitation, mm	370		676		516		517	
Surface Runoff, mm	10	34	119	46	136	41	88	40
Sediment								
Yield, kg	877	15	10,489	25	13,291	12	8,219	17
Yield, kg/ha	41	16	488	28	618	13	382	19
Avg. conc., mg/l	408	49	410	60	455	32	424	47

* Measurements Nov. 4, 1976 to Sep. 30, 1977.

† Measurements Oct. 1, 1978 to July 5, 1979.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 7. ESTIMATED DENSITY AND COVERAGE OF CATTLE FECAL DEPOSITS ON THE ROCK CREEK WATERSHED AT THREE TIMES DURING 1978.*

Date	Location	Density	Spatial Coverage
		(deposita/ha)	(Percent)
June 27	High use	4,900 (3,600 - 6,200)	2.5
	Drainage	1,760 (1,140 - 2,830)	0.9
	Watershed	1,000 (780 - 1,220)	0.5
August 20	High use	9,124 (7,800 - 10,380)	4.6
	Drainage	3,900 (2,860 - 4,940)	2.0
	Watershed	1,910 (1,600 - 2,200)	1.0
November 4	High use	12,400 (10,164 - 14,636)	6.2
	Drainage	4,700 (3,640 - 5,760)	2.4
	Watershed	2,560 (2,200 - 2,920)	1.4

---

* The estimates are stratified into high use sites, drainages, and the remaining part of the watershed.

This estimate may be affected by nonsampling error. See text.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE 8. NITROGEN AND P DISCHARGE FROM THE ROCK CREEK MAIN WATERSHED, 1977 WATER YEAR

Event dates	Water delivery	NO_3-N	Soluble NH_4+	TKN	Ortho P	Total P
	(m^3)	(Average mg/l)				
1976						
Dec 26-27,	158.3	0.17	0.13	-	1.0	-
1977						
Jan 16-19,	1,795.8	0.05	0.04	1.1	0.97	1.6
Feb 8-11	105.0	0.13	0.11	1.2	0.54	0.75
Feb 28-Mar 1	24.9	0.18	0.29	0.9	0.14	0.3
Mar 7-10	65.5	0.07	0.05	0.8	0.13	0.85
Mar 15-20	42.1	0.02	0.02	0.6	0.10	0.6
Mar 27-28	15.75	0.002	0.02	0.3	0.09	0.8
Apr 13-14	4.9	0.01	0.01	-	0.16	-
May 2-4	3.6	0.14	0.07	2.2	0.25	0.85
May 17-18	11.8	0.004	0.008	0.8	0.20	0.5
May 26-27	3.7	0.003	0.005	1.0	0.17	0.5
Jun 4	0.2	0.02	0.35	1.3	0.05	0.5
		g/ha				
Total delivery for water year	2,232	6.5	5.3		92	

EPA-287 (Cin.)
(4-76)

TABLE 9. NITROGEN AND P DISHCARGE FROM THE ROCK CREEK CHECK WATERSHED, 1977 WATER YEAR

Event dates	Water delivery	NO_3-N	Soluble NH_4^+	TKN	Ortho P	Total P
	(m^3)	---------------(Average mg/l)---------------				
1976						
Dec 26-27	82.9	0.05	0.10	-	0.32	-
1977						
Jan 16-19,	206.9	0.04	0.01	0.7	0.54	0.7
Feb 8-10	12.2	0.10	0.16	1.2	0.33	0.5
Mar 8-9	2.6	0.15	0.01	-	0.10	-
Mar 19	<1.0	0.015	0.02	-	0.16	-
Mar 27	<1.0	0.05	0.0	0.6	0.15	-
		--------------------g/ha----------------------				
Total delivery for water year	305	15.6	13.7		158	

TABLE 10. NITROGEN DISCHARGE FROM THE ROCK CREEK MAIN WATERSHED, 1978 WATER YEAR

Event dates	Water delivery	DIS NO_3-N	DIS NH_4-N	DIS ORG-N	DIS TKN	DIS T-N	T-N	Event type
	(m^3)	-----	-----	(Average mg/l)	-----	-----	-----	
1977								
Oct. 30-Nov. 2	15.6	0.74	0.28	1.15	1.44	2.11	3.42	Rain
Nov. 8	22.9	0.04	0.29	1.15	1.44	1.55	30.70	Pond draining
Nov. 13-16	26.0	0.07	0.13	0.58	0.73	0.78	1.38	Rain
Nov. 25-30	304.5	0.03	0.03	0.30	0.31	0.32	0.91	Snowmelt/rain
Dec. 1-4	172.3	0.21	0.18	0.95	1.07	1.31	1.80	Snowmelt/rain
Dec. 6-7	107.2	0.37	0.17	1.16	1.31	1.62	1.85	Snowmelt/rain
Dec. 10-15	6,717.9	0.36	0.02	1.10	1.12	1.46	8.10	Rain
1978								
Jan 5-9	5,874.6	0.40	0.01	0.66	0.67	1.08	1.65	Snowmelt/limited rain
Feb. 3-7	6,699.8	0.20	0.03	0.68	0.71	0.89	1.55	Snowmelt/rain
Feb. 26-Mar. 2	1,417.5	0.06	0.01	0.33	0.34	0.40	0.59	Snowmelt/rain
Mar 8-9	1,067.6	0.10	0.03	0.34	0.38	0.48	0.79	Rain
Mar. 12-15	1,152.4	0.09	0.01	0.53	0.54	0.64	0.74	Snowmelt
Apr. 1-7	1,518.6	0.13	0.01	0.90	0.91	1.06	1.19	Rain/sleet/snow
Apr. 16	122.7	0.12	0.04	0.92	0.97	1.09	1.25	Snow/hail/rain
Apr. 27-28	166.4	0.17	0.02	0.88	0.89	1.09	1.74	Rain
May 15-16	113.0	3.86	0.90	0.73	1.62	5.52	6.06	Rain
July 4	6.3	2.27	0.24	0.37	0.66	2.93	8.08	Rain
		-----	-----	-----	kg/ha	-----	-----	
Total delivery	25,505.0	0.33	0.04	0.90	0.94	1.25	3.80	
Baseflow	12,098.0	0.09	0.01	0.29	0.30	0.39	0.57	

(continued)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD, BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA

TABLE 10. (continued)

Event dates	ORG-N	TKN	T-N	T-N SED	EXCH-NH_4 SED	Event type
	-----(Average mg/l)-----					
1977						
Oct. 30-Nov. 2	2.32	2.62	3.42	1.41	0.24	Rain
Nov. 8	30.40	30.60	30.70	29.10	0.00	Pond draining
Nov. 13-16	1.18	1.29	1.38	0.60	0.00	Rain
Nov. 25-30	0.88	0.89	0.91	0.59	0.01	Snowmelt/rain
Dec. 1-4	1.33	1.58	1.80	0.49	0.10	Snowmelt/rain
Dec. 6-7	1.26	1.44	1.85	0.23	0.11	Snowmelt/rain
Dec. 10-15	7.72	7.74	8.10	6.64	0.02	Rain
1978						
Jan 5-9	1.21	1.24	1.65	0.57	0.02	Snowmelt/limited rain
Feb. 3-7	1.31	1.66	1.55	0.66	0.03	Snowmelt/rain
Feb. 26-Mar. 2	0.52	0.53	0.59	0.19	0.00	Snowmelt/rain
Mar 8-9	0.66	0.70	0.79	0.31	0.00	Rain
Mar. 12-15	0.64	0.65	0.74	0.10	0.00	Snowmelt
Apr. 1-7	1.04	1.06	1.19	0.13	0.00	Rain/sleet/snow
Apr. 16	1.09	1.14	1.25	0.16	0.00	Snow/hail/rain
Apr. 27-28	1.56	1.57	1.74	0.65	0.00	Rain
May 15-16	1.29	2.20	6.06	0.54	0.00	Rain
July 4	5.43	5.81	8.08	5.15	0.09	Rain
	-----(kg/ha)-----					
Total delivery	3.42	3.56	3.80	2.54	0.02	
Baseflow	0.47	0.48	0.57	0.18	0.005	

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSIONS FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 11. NITROGEN DISCHARGE FROM THE ROCK CREEK CHECK WATERSHED, 1978 WATER YEAR

Event dates	Water delivery	DIS NO_3-N	DIS NH_4-N	DIS ORG-N	DIS TKN	DIS T-N	Event type
	(m^3)	------------(Average mg/l)----------					
1977							
Nov 25-27	14.9	0.01	0.04	0.38	0.39	0.41	Snowmelt/rain
Dec 1-3	15.3	0.02	0.12	0.52	0.61	0.64	Snowmelt/rain
Dec 6-7	4.0	0.03	0.10	1.03	1.10	1.13	Snowmelt/rain
Dec 10-16	143.0	0.15	0.02	0.57	0.58	0.72	Rain
1978							
Jan 5-9	89.3	0.18	0.03	0.47	0.50	0.67	Snowmelt/limited rain
Feb 2-7	81.6	0.03	0.03	0.47	0.50	0.54	Snowmelt/rain
Feb 26-Mar 1	7.2	0.06	0.03	0.44	0.47	0.54	Snowmelt/rain
Mar 8-9	9.6	0.10	0.03	0.34	0.36	0.44	Rain
Mar 12-15	5.5	0.06	0.00	0.31	0.31	0.37	Snowmelt
Apr 1-7	23.6	0.21	0.01	1.10	1.11	1.32	Rain/sleet/snow
Apr 16	2.5	0.20	0.08	1.08	1.20	1.40	Snow/hail/rain
Apr 27-28	4.2	0.31	0.02	1.57	1.60	1.90	Rain
May 15-16	5.8	5.03	0.09	1.91	2.00	7.10	Rain
		-----------------(kg/ha)----------------					
Total delivery	407.0	0.08	0.01	0.26	0.28	0.36	

(continued)

TABLE 11. (continued)

Event dates	ORG-N	TKN	T-N	SED-N	EXCH-NH_4 SED	Event type
	-------------	-------------	(Average mg/l)	-------------	-------------	
1977						
Nov 25-27	0.76	0.80	0.81	0.40	0.02	Snowmelt/rain
Dec 1-3	1.08	1.19	1.21	0.57	0.01	Snowmelt/rain
Dec 6-7	1.17	1.24	1.28	0.15	0.01	Snowmelt/rain
Dec 10-16	0.75	0.78	0.93	0.21	0.03	Rain
1978						
Jan 5-9	0.83	0.85	1.03	0.36	0.00	Snowmelt/limited rain
Feb 2-7	0.66	0.70	0.73	0.19	0.00	Snowmelt/rain
Feb 26-Mar 1	0.58	0.65	0.72	0.18	0.04	Snowmelt/rain
Mar 8-9	0.70	0.73	0.81	0.37	0.01	Rain
Mar 12-15	0.58	0.64	0.71	0.34	0.07	Snowmelt
Apr 1-7	1.28	1.31	1.51	0.19	0.01	Rain/sleet/snow
Apr 16	1.52	1.60	1.80	0.40	0.00	Snow/hail/rain
Apr 27-28	1.95	1.98	2.26	0.36	0.00	Rain
May 15-16	2.14	2.24	7.30	0.20	0.00	Rain
	-------------	-------------	(kg/ha)	-------------	-------------	
Total delivery	0.38	0.39	0.48	0.12	0.004	

TABLE 12. NITROGEN DISCHARGE FROM THE ROCK CREEK MAIN WATERSHED, 1979 WATER YEAR

Event dates	Water delivery	DIS NO_3-N	DIS NH_4-N	DIS ORG-N	DIS TKN	DIS T-N	ORG-N	TKN	T-N	SED-N
	(m^3)	------------(Average mg/l)----------								
1978										
Nov 4	0.9	1.778	.667	2.111	2.78	4.56	3.00	3.67	5.44	.89
Nov 17	6.0	.950	.400	2.517	2.92	3.87	2.92	3.32	4.25	.38
Nov 30-Dec 4	65.6	.688	.072	.712	.78	1.47	.98	1.05	1.74	.27
Dec 11	96.7	.203	.114	.504	.62	.82	.58	6.91	.89	.07
Dec 23-24	68.4	.522	.010	.822	.83	1.35	1.08	1.09	1.62	.26
1979										
Feb 6-7	51.4	.837	.247	1.113	1.36	2.19	1.49	1.73	2.57	.37
Feb 9-14	12,523.2	1.731	.134	.944	1.08	2.81	2.11	2.24	3.97	1.16
Feb 18-20	1,254.6	.909	.082	.830	.91	1.82	.95	1.03	1.94	1.11
Feb 25-28	5,012.5	.668	.056	.580	.64	1.30	.84	.90	1.57	.26
Mar 4-8	4,968.2	.360	.050	.623	.67	1.03	.78	.83	1.19	.16
Mar 15-18	1,066.5	.141	.025	.861	.89	1.03	1.21	1.23	1.37	.33
Mar 27-28	532.2	.163	.079	.804	.88	1.05	1.18	1.26	1.45	.37
Apr 2-4	1,001.4	.067	.034	.747	.78	.85	1.05	1.08	1.15	.31
Apr 6-10	2,510.2	.109	.047	.739	.79	.89	1.06	1.11	1.21	.32
Apr 12-13	675.4	.091	.030	.729	.76	.85	1.42	1.45	1.54	.70
Apr 16-17	631.8	.101	.046	.906	.95	1.05	1.24	1.29	1.39	.34
Apr 23-24	623.5	.060	.039	.904	.94	1.00	1.21	1.25	1.31	.30
May 4-9	3,926.8	.224	.045	.748	.79	1.02	1.09	1.19	1.36	.35
		-----------------(kg/ha)-----------------								
Total delivery	35,015	1.33	.01	1.28	1.42	2.75	2.25	2.43	3.76	.96
Baseflow	5,618	.15	.01	.19	.20	.35	.24	.20	.35	.05

TABLE 13. NITROGEN DISCHARGE FROM THE ROCK CREEK CHECK WATERSHED, 1979 WATER YEAR

Event dates	Water delivery	DIS NO_3-N	DIS NH_4-N	DIS ORG-N	DIS TKN	DIS T-N
	(m^3)	------------(Average mg/l)------------				
1978						
Dec 3-4	10.2	.059	.0	.304	.304	0.37
Dec 11	18.9	.0	.0	.429	.429	0.43
Dec 23-24	11.1	.009	.0	.486	.486	0.49
1979						
Feb 6-7	2.9	.517	.103	1.000	1.100	1.66
Feb 9-15	170.1	.155	.036	.460	.50	0.65
Feb 17-20	12.1	.190	.025	.793	.82	1.01
Feb 25-28	42.4	.257	.024	.514	.54	0.79
Mar 4-7	15.8	.177	.025	.563	.57	0.78
Mar 16	1.7	.294	.059	.824	.88	1.12
Mar 27-28	6.4	.328	.062	1.172	1.23	1.56
Apr 2-4	4.7	.064	.064	.809	.87	0.92
Apr 6-9	15.1	.219	.066	1.020	1.09	1.31
Apr 12-13	4.2	.119	.048	.738	.79	.88
Apr 16-17	3.9	.179	.103	1.103	1.21	1.38
Apr 24	6.7	.090	.045	1.164	1.21	1.30
May 4-6	43.9	.248	.039	.911	.95	1.20
		----------------(kg/ha)----------------				
Total delivery	370	.07	.01	0.25	0.26	0.33

(continued)

TABLE 13. (continued)

Event dates	ORG-N	TKN	T-N	SED-N
	(Average mg/l)			
1978				
Dec 3-4	0.36	0.36	0.43	0.06
Dec 11	0.54	0.54	0.54	0.11
Dec 23-24	0.53	0.53	0.54	0.05
1979				
Feb 6-7	2.03	2.17	2.69	1.03
Feb 9-15	0.79	0.82	0.98	0.33
Feb 17-20	1.24	1.27	1.46	0.45
Feb 25-28	0.79	0.82	1.07	0.28
Mar 4-7	0.89	0.92	1.11	0.33
Mar 16	1.47	1.53	1.77	0.65
Mar 27-28	1.77	1.83	2.17	0.61
Apr 2-4	1.02	1.09	1.17	0.25
Apr 6-9	1.36	1.43	1.65	0.34
Apr 12-13	1.47	1.52	1.62	0.74
Apr 16-17	1.46	1.56	1.74	0.36
Apr 24	1.37	1.42	1.51	0.21
May 4-6	1.21	1.25	1.50	0.30
	(kg/ha)			
Total delivery	0.37	0.39	0.46	0.13

TABLE 14. PHOSPHORUS DISCHARGE FROM THE ROCK CREEK MAIN WATERSHED, 1978 WATER YEAR

Event dates	Water delivery	DIS Ortho-P	T-DIS-P	T-P	T-Sed-P	Event type
	(m^3)	------------(Average mg/l)----------				
1977						
Oct 30-Nov 2	15.6	.29	.47	.88	.41	Rain
Nov 8	22.9	.13	.35	10.80	10.40	Pond draining
Nov 13-16	26.0	.17	.21	.30	.09	Rain
Nov 25-30	304.5	.28	.33	.48	.15	Snowmelt/rain
Dec 1-4	172.3	.21	.23	.53	.31	Snowmelt/rain
Dec 6-7	107.2	.18	.26	.39	.13	Snowmelt/rain
Dec 10-15	6,717.9	.25	.40	3.12	2.72	Rain
1978						
Jan 5-9	5,874.6	.16	.20	.25	.05	Snowmelt/limited rain
Feb 3-7	6,699.8	.16	.20	.42	.22	Snowmelt/rain
Feb 26-Mar 2	1,417.5	.09	.19	.24	.05	Snowmelt/rain
Mar 8-9	1,067.6	.07	.13	.29	.16	Rain
Mar 12-15	1,152.4	.07	.15	.24	.09	Snowmelt
Apr 1-7	1,518.6	.08	.17	.35	.18	Rain/sleet/snow
Apr 16	122.7	.08	.16	.29	.12	Snow/hail/rain
Apr 27-28	166.4	.09	.14	.32	.18	Rain
May 15-6	113.0	.29	.53	.78	.24	Rain
July 4	6.3	.84	1.25	1.79	.54	Rain
		----------------(kg/ha)----------------				
Total delivery	25,505	0.2	0.3	1.27	0.98	
Baseflow delivery	12,098	0.07	0.09	0.12	0.03	

EPA-287 (Cin.)
(4-76)

TABLE 15. PHOSPHORUS DISCHARGES FROM THE ROCK CREEK CHECK WATERSHED, 1978 WATER YEAR

Event dates	Water delivery	DIS Ortho-P	T-DIS-P	T-P	T-Sed-P	Event type
	(m^3)	------------(Average mg/l)----------				
1977						
Nov 25-27	14.9	.07	.11	.40	.29	Snowmelt/rain
Dec 1-3	15.3	.07	.09	.25	.16	Snowmelt/rain
Dec 6-7	4.0	.03	.05	.23	.18	Snowmelt/rain
Dec 10-16	143.0	.03	.11	.25	.14	Rain
1978						
Jan 5-9	89.3	.03	.12	.15	.03	Snowmelt/limited rain
Feb 2-7	81.6	.04	.12	.24	.12	Snowmelt/rain
Feb 26-Mar 1	7.2	.01	.03	.10	.07	Snowmelt/rain
Mar 8-9	9.6	.02	.06	.20	.14	Rain
Mar 12-15	5.5	.01	.05	.16	.11	Snowmelt
Apr 1-7	23.6	.03	.12	.26	.14	Rain/sleet/snow
Apr 16	2.5	.04	.14	.28	.14	Snow/hail/rain
Apr 27-28	4.2	.05	.15	.29	.14	Rain
May 15-16	5.8	.03	.10	.25	.15	Rain
		----------------(kg/ha)----------------				
Total delivery	407.0	0.01	0.05	0.1	0.05	

TABLE 16. PHOSPHORUS DISCHARGES FROM THE ROCK CREEK MAIN WATERSHED, 1979 WATER YEAR

Event dates	Water delivery	DIS Ortho-P	T-DIS-P	T-P	T-Sed-P
	(M^3)	------------(Average mg/l)----------			
1978					
Nov 4	0.9	1.00	1.44	1.67	.22
Nov 17	6.0	.73	1.09	1.23	.13
Nov 30-Dec 4	65.6	.51	.56	.63	.07
Dec 11	96.7	.43	.55	.74	.20
Dec 23-24	68.4	.20	.32	.37	.05
1978					
Feb 6-7	51.4	.23	.28	.43	.17
Feb 9-14	12,523.2	.32	.47	.94	.47
Feb 18-20	1,254.6	.25	.31	.38	.07
Feb 25-28	5,012.5	.18	.23	.34	.11
Mar 4-8	4,968.2	.24	.29	.44	.15
Mar 15-18	1,066.5	.20	.23	.37	.14
Mar 27-28	532.2	.18	.24	.37	.13
Apr 2-4	1,001.4	.12	.16	.20	.04
Apr 6-10	2,510.2	.14	.30	.43	.13
Apr 12-13	675.4	.15	.24	.41	.16
Apr 16-17	631.8	.18	.23	.27	.04
Apr 23-24	623.5	.13	.22	.31	.08
May 4-9	3,926.8	.08	.22	.34	.13
		----------------(kg/ha)----------------			
Total delivery	35,015	0.36	0.54	0.93	0.39
Baseflow delivery	5,618	0.05	0.08	0.12	0.04

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 17. PHOSPHORUS DISCHARGES FROM THE ROCK CREEK CHECK WATERSHED, 1979 WATER YEAR

Event dates	Water delivery	DIS Ortho-P	T-DIS-P	T-P	T-Sed-P
	(M^3)	------------(Average mg/l)----------			
1978					
Dec 3-4	10.2	0.03	.05	.08	.03
Dec 11	18.9	0.04	.07	.13	.06
Dec 23-24	11.1	0.01	.02	.03	.01
Feb 6-7	2.9	0.10	.17	.45	.28
Feb 9-15	170.1	0.04	.06	.13	.07
Feb 17-20	12.1	0.05	.05	.17	.12
Feb 25-28	42.4	0.04	.05	.14	.09
1979					
Mar 4-7	15.8	0.07	.08	.18	.10
Mar 16	1.7	0.12	.18	.41	.24
Mar 27-28	6.4	0.19	.20	.41	.21
Apr 2-4	4.7	0.09	.09	.18	.09
Apr 6-9	15.1	0.05	.23	.49	.26
Apr 12-13	4.2	0.02	.07	.24	.17
Apr 16-17	3.9	0.10	.13	.28	.15
Apr 24	6.7	0.06	.14	.30	.16
May 4-6	43.9	0.04	.14	.26	.12
		---------------(kg/ha)---------------			
Total delivery	370.0	0.02	0.04	0.07	0.04

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

TABLE 18. AVERAGE CONCENTRATIONS OF FC, FS, AND TC IN RUNOFF FROM THE ROCK CREEK MAIN WATERSHED, 1977 WATER YEAR

Event dates	Water delivery	Total C	Fecal C	Fecal S	FC/FS	Event type
	(M^3)	(Average No./100 ml)				
1976						
Dec. 26-27	158.3					Snowmelt/rain
1977						
Jan 16-19	1,795.8	13,850	395	6,780	0.06	Snowmelt/rain
Feb. 8-11	105.0	200,000	3,300	3,300	1.00	Snowmelt/rain
Feb. 28-Mar 1	24.9	34,000	72	250	0.30	Snowmelt/rain
Mar. 7-10	65.5	24,000	69	91	0.76	Rain/snow/rain
Mar. 15-20	52.1	5,600	31	31	1.00	Snowmelt/rain
Mar. 27-28	15.75	5,300	11	52	0.20	Snowmelt/rain
Apr. 13-14	4.9	3.7×10^6	710	8,250	0.09	Rain
May 2-4	3.6	3.2×10^6	3,660	8,450	0.40	Rain
May 17-18	11.8	276,000	177	1,650	0.10	Rain
May 26-27	3.7	1.0×10^6	290	2,510	0.10	Rain
June 4	0.2	8.8×10^6	26,000	1,400,000	0.02	Rain

TABLE 19. AVERAGE CONCENTRATIONS OF FC, FS, AND TC IN RUNOFF FROM THE ROCK CREEK CHECK WATERSHED, 1977 WATER YEAR

Event dates	Water delivery	Total C	Fecal C	Fecal S	FC/FS	Event type
	(M^3)	----------------------(Average No./100 ml)----------------------				
1976 Dec. 26–27	82.9					Snowmelt/rain
1977 Jan. 16–19	206.9	5,800		6,200		Snowmelt/rain
Feb. 8–10	12.2	24,600	500	4,900	0.1	Snowmelt/rain
Mar. 8–9	2.6	23,900	110	750	0.1	Rain/snow/rain
Mar. 19	<1.0	15,400	90	160	0.6	
Mar. 27	<1.0	7,800	200	50	4.0	

TABLE 20. AVERAGE CONCENTRATIONS OF FC, FS, AND TC IN RUNOFF FROM THE ROCK CREEK MAIN WATERSHED, 1978 WATER YEAR

Event dates	Water delivery	Total C	Fecal C	Fecal S	FC/FS	Event type
	(M^3)	-----------------------	(Average No./100 ml)	-----------------------		
1977						
Oct. 30-Nov. 2	15.6	369,000	18,000	46,000	0.39	Rain
Nov. 8	22.9	677,000	74,000	633,000	0.12	Pond draining
Nov. 13-16	26.0	185,000	9,000	10,900	0.90	Rain
Nov. 25-30	304.5	524,000	10,000	8,500	1.18	Snowmelt/rain
Dec. 1-4	172.3	161,000	8,000	12,000	0.67	Snowmelt/rain
Dec. 6-7	107.2	223,000	8,000	12,000	0.67	Snowmelt/rain
Dec. 10-15	6,717.9	163,000	3,800	3,800	1.00	Rain
1978						
Jan 5-9	5,874.6	32,000	250	340	0.74	Snowmelt/limited rain
Feb. 3-7	6,699.4	19,700	170	200	0.85	Snowmelt/rain
Feb. 26-Mar. 2	1,417.5	21,800	70	110	0.91	Snowmelt/rain
Mar. 8-9	1,067.6	11,100	60	80	0.75	Rain
Mar. 12-15	1,152.4	8,400	40	75	0.53	Snowmelt
Apr. 1-7	1,518.6	76,000	250	620	0.40	Rain/sleet/snow
Apr. 16	122.7	106,000	630	3,400	0.19	Snow/hail/rain
Apr. 27-28	166.4	89,000	1,000	2,400	0.42	Rain
May 15-16	113.0	494,000	5,400	7,300	0.74	Rain
July 4	6.3	5,600,000	187,000	600,000	0.31	Rain
Total water delivery	25,505.0					
Base flow water delivery and bacteria concentrations	12,098.0	23,000	150	420	0.36	

TABLE 21. AVERAGE CONCENTRATIONS OF FC, FS, AND TC IN RUNOFF FROM THE ROCK CREEK CHECK WATERSHED, 1978 WATER YEAR

Event dates	Water delivery	Total C	Fecal C	Fecal S	FC/FS	Event type
	(M^3)	(Average No./100 ml)				
1977						
Nov. 25-27	14.9	702,000	210	5,900	0.04	Snowmelt/rain
Dec. 1-3	15.3	248,000	130	7,400	0.02	Snowmelt/rain
Dec. 6-7	4.0	308,000	50	8,400	0.01	Snowmelt/rain
Dec. 10-16	143.0	116,000	100	2,500	0.04	Rain
1978						
Jan 5-9	89.3	26,000	30	220	0.14	Snowmelt/limited rain
Feb. 2-8	81.6	14,900	10	100	0.10	Snowmelt/rain
Feb. 26-Mar. 1	7.2	24,600	5	20	0.25	Snowmelt/rain
Mar. 8-9	9.6	16,100	4	30	0.13	Rain
Mar. 12-15	5.5	13,700	10	20	0.50	Snowmelt
Apr. 1-7	23.6	205,000	40	2,400	0.02	Rain/sleet/snow
Apr. 16	2.5	149,000	35	10,400	0.003	Snow/hail/rain
Apr. 27-28	4.2	143,000	200	10,700	0.02	Rain
May 15-16	5.8	481,000	160	43,000	0.003	Rain
Total water delivery	407.0					

TYPING GUIDE SHEET

TABLE 22. AVERAGE CONCENTRATIONS OF FC, FS, AND TC IN RUNOFF FROM THE ROCK CREEK MAIN WATERSHED, 1979 WATER YEAR

Event dates	Water delivery	Total C	Fecal C	Fecal S	FC/FS
	(m^3)	------------(Average No./100 ml)-----------			
1978					
Nov. 4	0.9	1,522,000	26,800	62,300	0.43
Nov. 17	6.0	313,300	24,500	72,200	0.34
Nov. 30-Dec. 4	65.6	37,800	800	4,600	0.17
Dec. 11	96.7	30,300	500	6,500	0.09
Dec. 23-24	68.4	22,700	1,100	1,000	1.10
1979					
Feb. 6-7	51.4	101,700	300	6,300	0.04
Feb. 9-14	12,523.2	58,900	200	2,400	0.08
Feb. 18-20	1,254.6	18,000	80	500	0.16
Feb. 25-28	5,012.5	7,900	70	1,200	0.06
Mar. 4-8	4,968.2	5,600	60	400	0.15
Mar. 15-18	1,066.5	38,300	50	400	0.13
Mar. 27-28	532.2	27,200	100	1,000	0.10
Apr. 2-4	1,001.4	10,600	40	200	0.20
Apr. 6-10	2,510.2	10,000	90	400	0.23
Apr. 12-13	675.4	2,600	300	200	1.50
Apr. 16-17	631.8	10,700	90	700	0.13
Apr. 23-24	623.5	26,200	200	700	0.29
May 4-9	3,926.8	37,800	1,200	2,100	0.58
Total water delivery	35,015.0				
Base flow water delivery and bacteria concentrations	5,618.0	21,900	120	420	0.29

TABLE 23. AVERAGE CONCENTRATIONS OF FC, FS, AND TC IN RUNOFF FROM THE ROCK CREEK CHECK WATERSHED, 1979 WATER YEAR

Event dates	Water delivery	Total C	Fecal C	Fecal S	FC/FS
	(M^3)	------------(Average No./100 ml)-----------			
1978					
Dec. 3-4	10.2	68,500	8	1,500	.005
Dec. 11	18.9	31,200	4	1,500	.003
Dec. 23-24	11.1	20,800	3	1,500	.002
1979					
Feb 6-7	2.9	53,500	2	3,600	.006
Feb. 9-15	170.1	22,600	2	1,300	.002
Feb. 17-20	12.1	7,400	2	360	.006
Feb. 25-28	42.4	9,000	4	830	.005
Mar. 4-7	15.8	3,700	3	450	.007
Mar. 16	1.7	16,000	3	1,300	.002
Mar. 27-28	6.4	16,400	2	4,400	.001
Apr. 2-4	4.7	8,000	2	320	.006
Apr. 6-9	15.1	20,700	13	640	.020
Apr. 12-13	4.2	2,900	9	1,800	.005
Apr. 16-17	3.9	30,900	5	1,800	.005
Apr. 24	6.7	40,200	2	1,500	.001
May 4-6	43.9	116,000	13	3,600	.004
Total water delivery	370.0				

TABLE 24. BACTERIOLOGICAL WATER QUALITY STANDARDS (SURFACE WATERS)*

Water use	Total C	Fecal C
	----------(No./100 ml)----------	
Recreation		
Primary contact	1,000	200
Partial contact	5,000	1,000
Public water supply	10,000	2,000

* U.S. Department of Interior, Federal Water Pollution Control Administration. 1968. A report of the Committee on Water Quality Criteria. Washington, D.C.

TABLE 25. WATER QUALITY PARAMETER CONCENTRATION RESPONSES TO STREAMFLOW

Parameter	Type of runoff event	Time of year	Response to streamflow
Bacteria, oxygen demands, N and P nutrients	Rainfall	Fall and spring	Direct response to streamflow changes with successively smaller peak concentration
"	Snowmelt or frozen ground rainfall	Winter	Little or inverse response to streamflow
"	Mixed (snowmelt followed by rainfall)	Fall, winter, and spring	Little response during snowmelt. Direct response to rainfall
"	Snowmelt or rainfall	Late winter and/or	Little response to streamflow changes
Specific conductance, pH, Cl, Na, K, Ca, Mg	Snowmelt or rainfall	Fall, winter, and spring	Inverse response to streamflow

TABLE 26. AVERAGE PERCENT FECAL COVERAGE IN THE DRAINAGE SAMPLED WITHIN THE STUDY WATERSHED, NOV. 4, 1978

Sampling site No.	Drainage runoff areas	Fecal coverage percent area
1	Sacrifice (lower) pasture (plus rest of grazed main watershed)	20*
2	Ungrazed (check) watershed	0
11	Southeast area just above main sampling station	NS
12	Northeast area just above main sampling station	0.7
13	All of the grazed watershed except the southeast, northeast and sacrifice areas	2.6
14	North pasture area draining into large gulley channel	0.9
15	Northwest pasture area	3.1
16	Southwest pasture area	2.2
17	Woodland area	1.8
18	Logged area (outside of fenced cattle grazed area, horses however were grazed here)	NS†

*Total remainder of watershed averaged 1.4 percent.

† NS = Not sampled.

TABLE 27. WITHIN WATERSHED INDICATOR BACTERIA RESULTS*

Sampling site	Date	Time	Flow (l/sec)	Fecal coliforms	Fecal strep	FC/FS
				-----No/100 ml------		
18	6 Dec 77	1535	–[†]	4,000	17,000	0.24
16	6 Dec 77	1530	–	10,000	28,000	0.36
14	6 Dec 77	1520	–	18,400	23,000	0.80
13	6 Dec 77	1515	–	12,800	20,000	0.64
1	6 Dec 77	1500	1.41	11,000	75,000	0.44
2	6 Dec 77	1600	0.05	70	6,000	0.01
18	13 Dec 77	1300[‡]	–	1,500	2,000	0.75
17	13 Dec 77	1300	–	300	2,200	0.14
16	13 Dec 77	1300	–	300	3,100	0.10
15	13 Dec 77	1300	–	320	4,700	0.07
14	13 Dec 77	1300	–	1,700	7,400	0.23
13	13 Dec 77	1300	–	480	5,400	0.09
12	13 Dec 77	1300	–	700	3,500	0.20
11	13 Dec 77	1300	–	200	2,700	0.30
1	13 Dec 77	1300	42.10	800	2,700	0.30
2	12 Dec 77	1300	0.01	4	400	0.01
18	15 Mar 78	1222		410	100	4.10
17	15 Mar 78	1216		10	30	.03
16	15 Mar 78	1212		30	215	.14
15	15 Mar 78	1211		60	70	.86
14	15 Mar 78	1208		50	105	0.48
13	15 Mar 78	1207		90	150	0.60
12	15 Mar 78	1205		60	35	1.71
11	15 Mar 78	1204		10	10	1.00
1	15 Mar 78	1200	10.24	155	150	1.03
2	15 Mar 78	1200	0.70	–	30	–
18	13 Feb 79	1050	–	36	1540	0.02
17	13 Feb 79	1100	–	12	460	0.03
16	13 Feb 79	1105	–	56	680	0.08
15	13 Feb 79	1107	–	16	640	0.02
14	13 Feb 79	1110	–	32	620	0.05
13	13 Feb 79	1113	–	36	600	0.06
12	13 Feb 79	1115	–	40	1720	0.05
11	13 Feb 79	1120	–	4	760	0.01
1	13 Feb 79	1200	73.27	230	460	0.50
2	13 Feb 79	1200	0.68	0	1140	–
18	27 Feb 79	1136	–	–	300	–
17	27 Feb 79	1140	–	–	100	–

(continued)

TABLE 27 (continued)

Sampling site	Date	Time	Flow (l/sec)	Fecal coliforms	Fecal strep	FC/FS
				-----No/100 ml------		
16	27 Feb 79	1143	–	–	370	–
15	27 Feb 79	1145	–	–	250	–
14	27 Feb 79	1130	–	–	210	–
13	27 Feb 79	1152	–	–	370	–
12	27 Feb 79	1155	–	12	370	0.04
11	27 Feb 79	1154	–	4	300	0.01
1	27 Feb 79	1200	13.0	40	370	0.11
2	27 Feb 79	1300	0.18	0	160	–
18	6 Apr 79	1010	–	225	1,800	0.13
17	6 Apr 79	1025	–	10	110	0.09
16	6 Apr 79	1030	–	160	600	0.27
15	6 Apr 79	1035	–	55	490	0.11
14	6 Apr 79	1040	–	550	970	0.57
13	6 Apr 79	1045	–	130	830	0.16
12	6 Apr 79	1050	–	545	1,290	0.42
11	6 Apr 79	1055	–	70	620	0.11
1	6 Apr 79	1100	10.96	205	1,170	0.18
2	6 Apr 79	1125	0.14	0	370	–
18	4 May 79	1200	–	2,700	8,000	0.34
17	4 May 79	1202	–	90	4,900	0.02
16	4 May 79	1205	–	2,230	20,000	0.11
15	4 May 79	1208	–	200	1,900	0.11
14	4 May 79	1210	–	50	100	0.50
13	4 May 79	1210	–	2,400	15,000	0.16
12	4 May 79	1214	–	1,400	19,000	0.07
11	4 May 79	1212	–	1,590	18,000	0.09
1	4 May 79	1215	2.36	5,300	12,000	0.44
2	4 May 79	1215	0.01	5	7,900	0.01

* See Figure 2 for sampling locations and associated runoff areas.

† No flow estimate made.

‡ Time approximately only.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 28. WITHIN WATERSHED N AND P RESULTS*

Sampling site	Date	Time	Flow (l/sec)	(mg/l)	Total N (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)
18	6 Dec 77	1535	-	0.03	1.30	0.31	0.53
16	6 Dec 77	1530	-	0.03	1.20	0.40	0.49
14	6 Dec 77	1520	-	0.11	1.70	0.09	0.31
13	6 Dec 77	1515	-	0.83	2.40	0.03	0.79
1	6 Dec 77	1500	1.41	0.50	0.93	0.16	0.27
2	6 Dec 77	1600	0.05	0.03	1.20	0.02	0.22
18	13 Dec 77	1300†	-	0.78	3.60	0.22	2.10
17	13 Dec 77	1300	-	0.12	1.6	0.16	0.77
16	13 Dec 77	1300	-	0.01	1.2	0.35	0.77
15	13 Dec 77	1300	-	0.13	1.8	0.13	0.66
14	13 Dec 77	1300	-	0.07	2.5	0.09	0.21
13	13 Dec 77	1300	-	0.55	3.3	0.28	1.60
12	13 Dec 77	1300	-	0.14	1.4	0.07	0.51
11	13 Dec 77	1300	-	0.58	1.5	0.39	0.53
1	13 Dec 77	1300	42.10	0.58	3.5	0.23	1.30
2	12 Dec 77	1300	0.01	0.28	0.7	0.06	0.23
18	15 Mar 78	1222	-	0.43	4.3	0.12	2.40
17	15 Mar 78	1216	-	0.12	1.6	0.14	0.65
16	15 Mar 78	1212	-	0.01	-	0.15	0.38
15	15 Mar 78	1211	-	0.01	-	0.08	0.20
14	15 Mar 78	1208	-	0.06	1.0	0.10	0.26
13	15 Mar 78	1207	-	0.07	1.4	0.09	0.72
12	15 Mar 78	1205	-	0.02	-	0.02	0.14
11	15 Mar 78	1204	-	0.01	0.41	0.09	0.19
1	15 Mar 78	1200	10.24	0.10	1.40	0.07	0.28
2	15 Mar 78	1200	0.20	0.05	0.55	0.01	0.15
18	13 Feb 79	1050	-	3.78	5.59	0.26	0.48
17	13 Feb 79	1100	-	0.36	1.36	0.18	0.40
16	13 Feb 79	1105	-	3.13	4.78	0.40	0.76
15	13 Feb 79	1107	-	0.83	2.54	0.24	0.38
14	13 Feb 79	1110	-	1.78	2.59	0.19	0.26
13	13 Feb 79	1113	-	1.97	3.32	0.44	0.57
12	13 Feb 79	1115	-	1.10	2.22	0.23	0.35
11	13 Feb 79	1120	-	0.15	0.99	0.32	0.41
1	13 Feb 79	1200	72.27	1.63	3.02	0.27	0.57
2	13 Feb 79	1200	0.68	0.18	0.85	0.03	0.13
18	27 Feb 79	1136	-	1.21	1.82	0.14	0.28
17	27 Feb 79	1140	-	0.21	0.74	0.14	0.23
16	27 Feb 79	1143	-	1.08	1.93	0.22	0.40
15	27 Feb 79	1145	-	0.34	1.17	0.12	0.18

(continued)

BEGIN LAST LINE OF TEXT
3/4"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 28 (continued)

Sampling site	Date	Time	Flow ---(l/sec)	(mg/l)	Total N (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)
14	27 Feb 79	1150	-	0.52	1.01	0.06	0.10
13	27 Feb 79	1152	-	0.76	1.56	0.21	0.37
12	27 Feb 79	1155	-	0.19	0.82	0.09	0.11
11	27 Feb 79	1154	-	0.50	1.17	0.23	0.40
1	27 Feb 79	1200	13.00	0.67	1.37	0.16	0.23
2	27 Feb 79	1300	0.18	0.25	0.86	0.01	0.05
18	6 Apr 79	1020	-	0.23	2.97	0.14	1.77
17	6 Apr 79	1025	-	0.04	0.82	0.10	0.30
16	6 Apr 79	1030	-	0.05	1.28	0.26	0.45
15	6 Apr 79	1035	-	0.08	1.15	0.05	0.08
14	6 Apr 79	1040	-	0.10	1.26	0.07	0.11
13	6 Apr 79	1045	-	0.08	1.19	0.25	0.30
12	6 Apr 79	1050	-	0.07	1.23	0.08	0.17
11	6 Apr 79	1055	-	0.06	1.43	0.11	0.18
1	6 Apr 79	1100	10.96	0.07	1.42	0.17	0.34
2	6 Apr 79	1125	0.14	0.14	1.90	0.10	0.28
18	4 May 79	1200	-	1.00	2.67	0.04	0.97
17	4 May 79	1202	-	0.14	1.27	0.07	0.37
16	4 May 79	1205	-	0.19	2.33	0.29	0.82
15	4 May 79	1208	-	0.11	1.61	0.12	0.26
14	4 May 79	1210	-	0.13	1.47	0.04	0.30
13	4 May 79	1210	-	0.12	2.29	0.15	0.74
12	4 May 79	1214	-	0.25	2.31	0.06	0.37
11	4 May 79	1212	-	0.16	2.77	0.09	0.46
1	4 May 79	1215	2.36	0.14	2.01	0.07	0.50
2	4 May 79	1215	0.20	0.34	2.26	0.07	0.30

* See Figure 2 for sampling locations and associated runoff areas.

† Time only approximate.

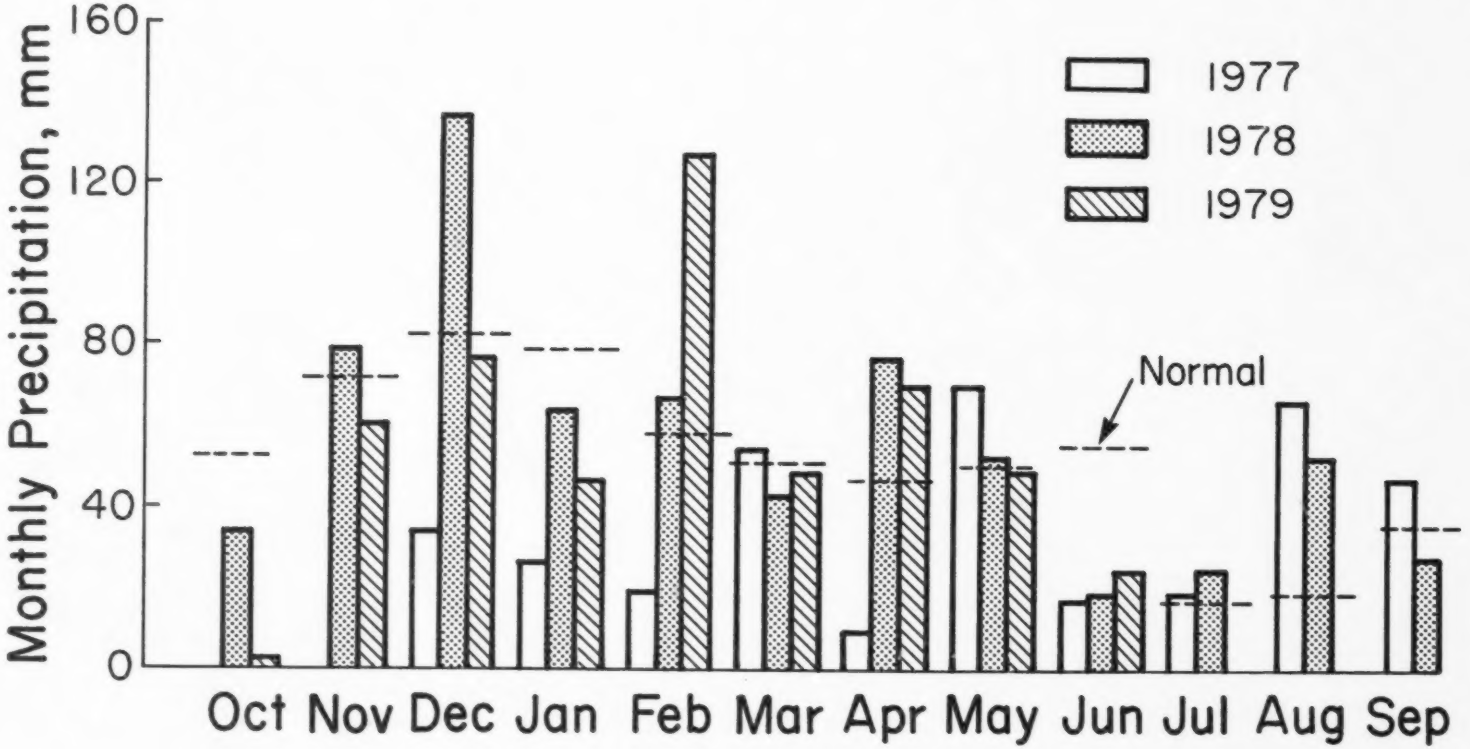


Figure 3. Observed watershed monthly precipitation and normal precipitation (Potlatch, Idaho)

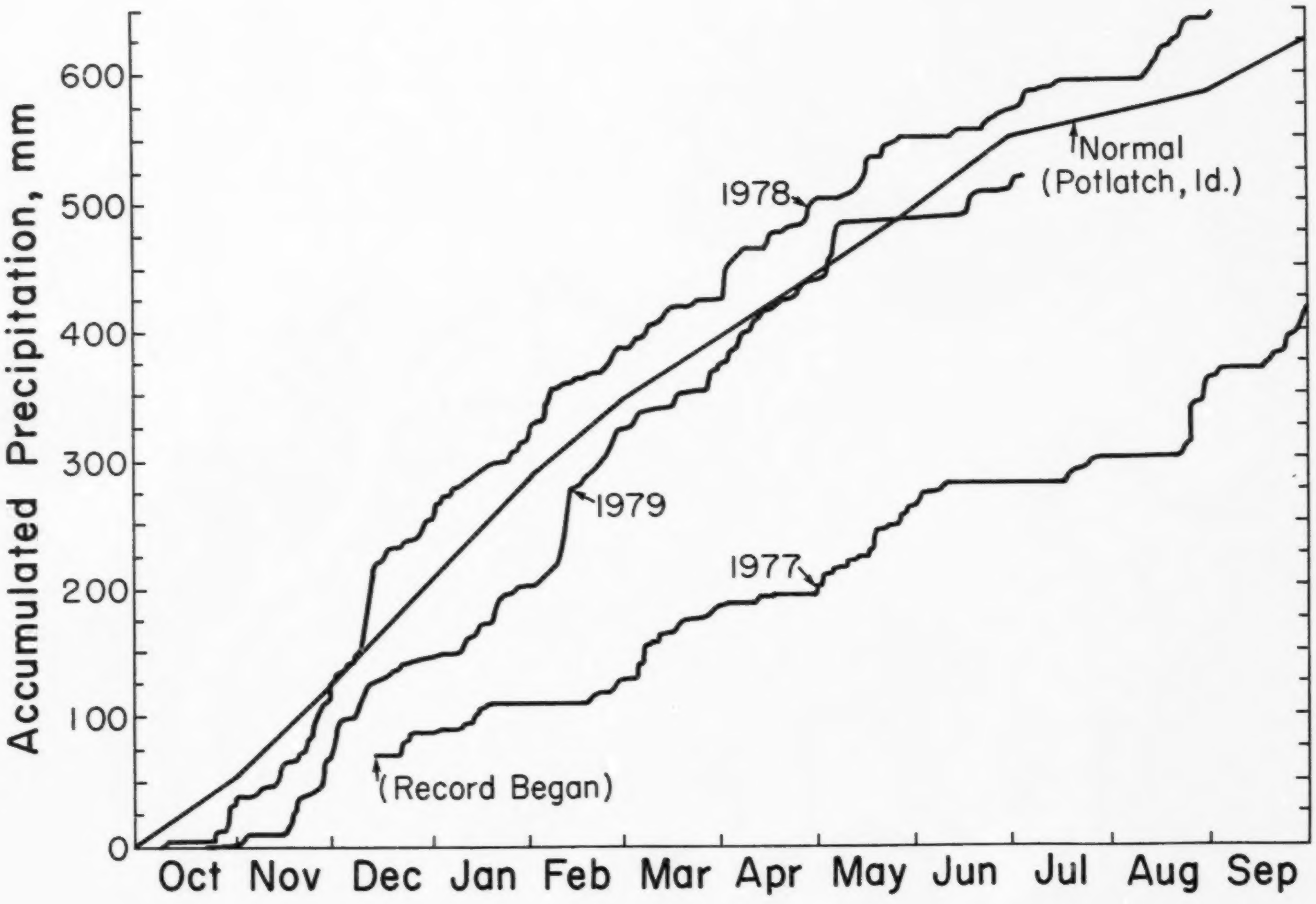


Figure 4. Accumulative daily precipitation and normal precipitation.

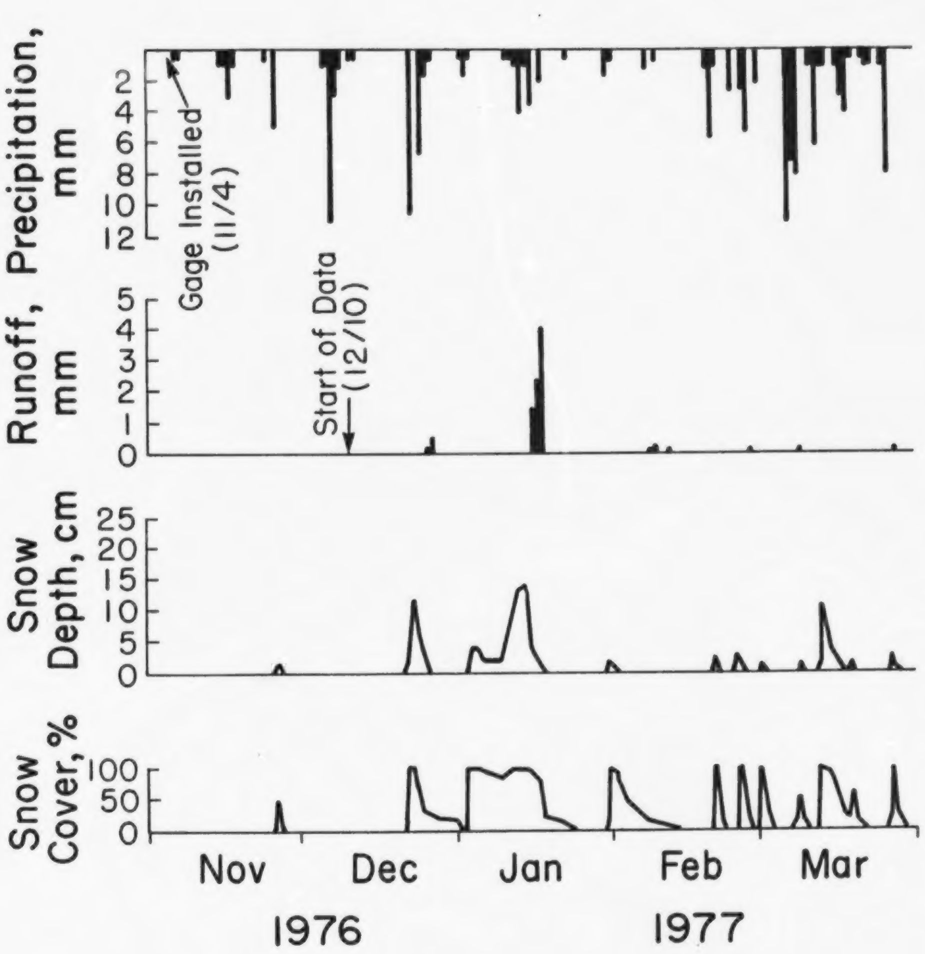


Figure 5. Runoff season hydrologic summary for main watershed, 1976-77.

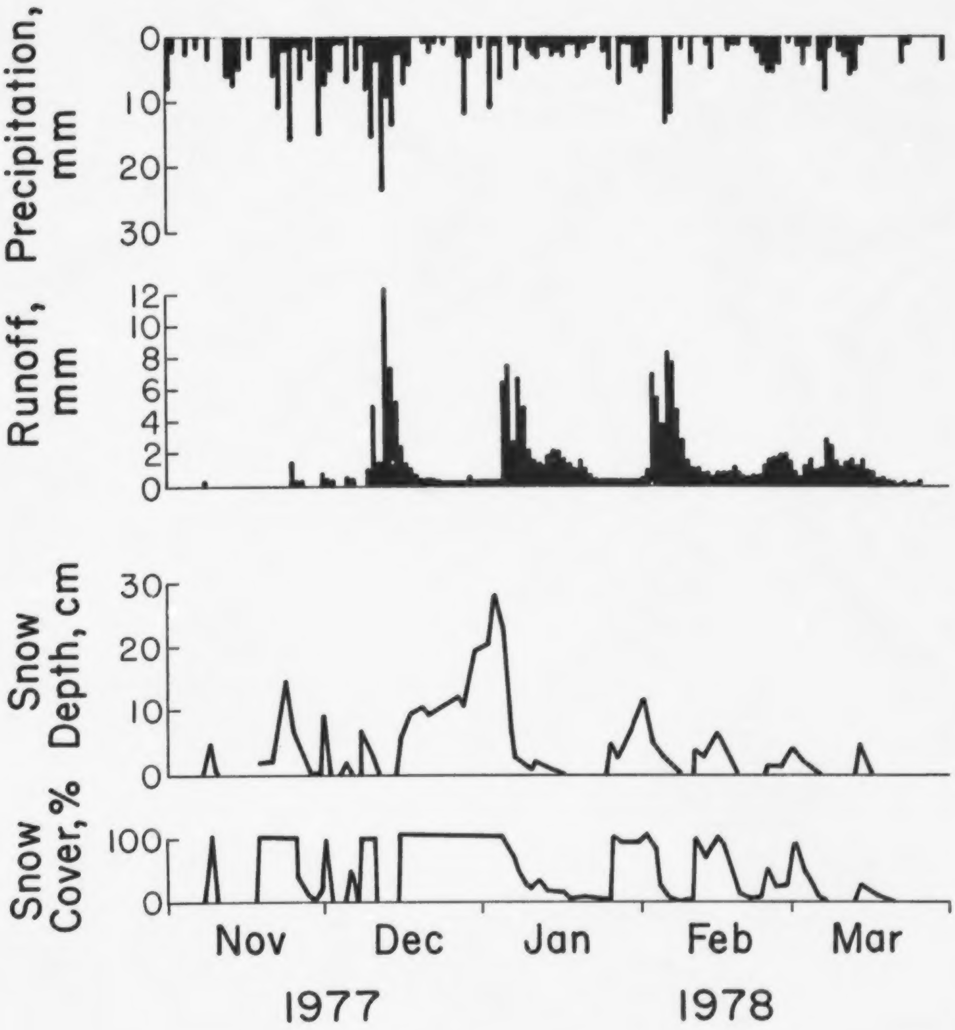


Figure 6. Runoff season hydrologic summary for main watershed, 1977-78

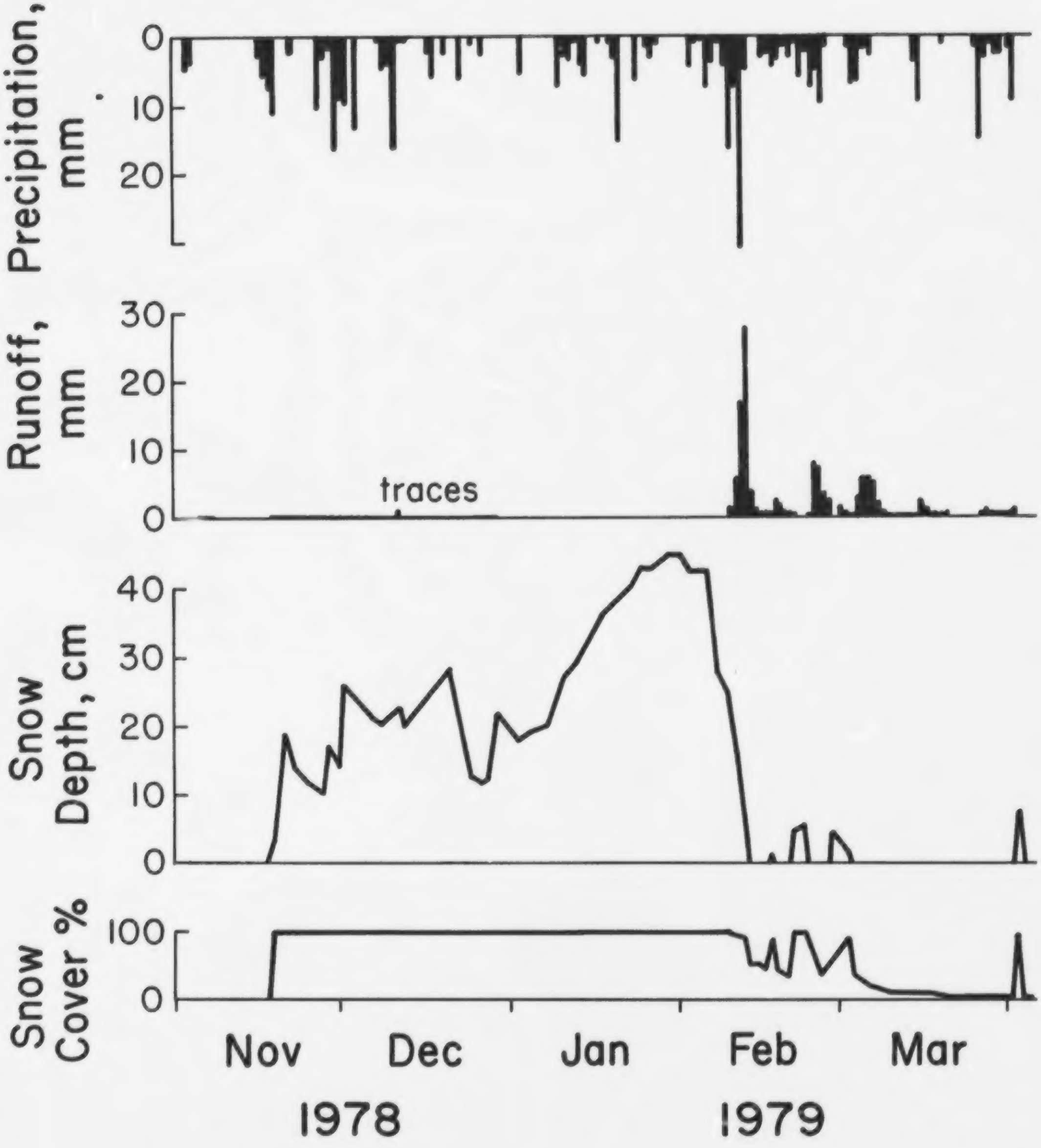


Figure 7. Runoff season hydrologic summary for main watershed, 1978-79.

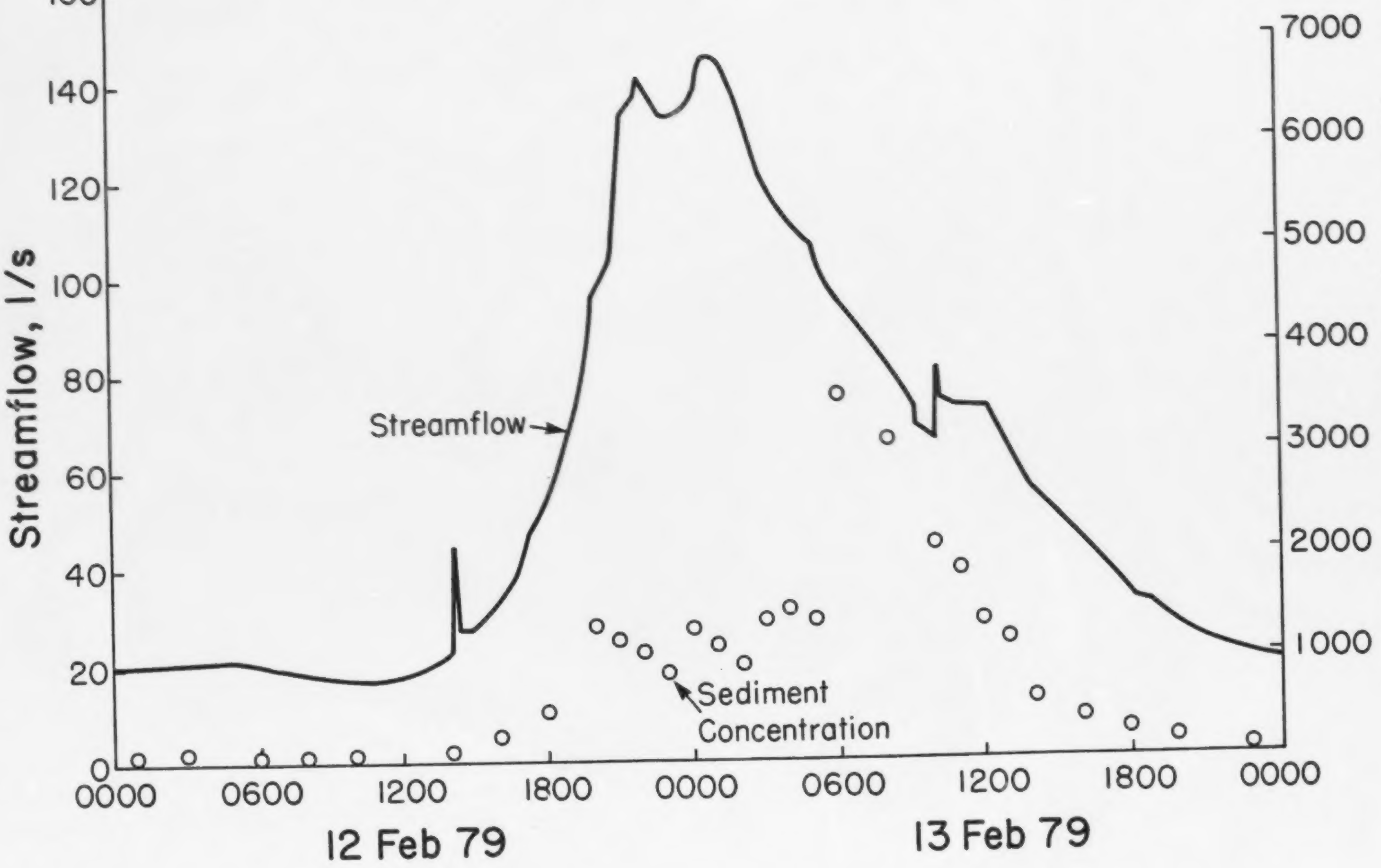


Figure 8. Runoff hydrograph from the main study watershed.

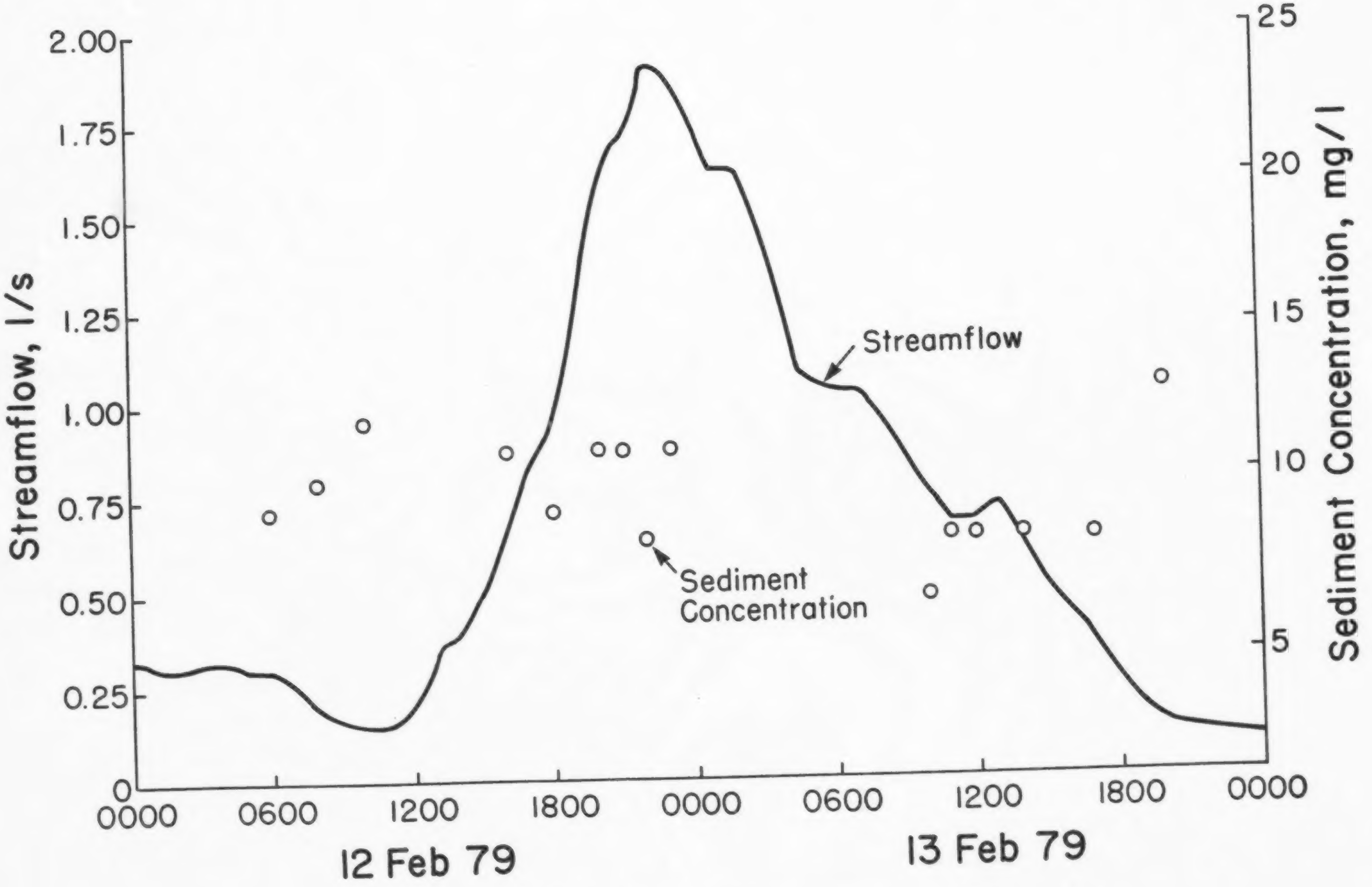


Figure 9. Runoff hydrograph from the check study watershed.

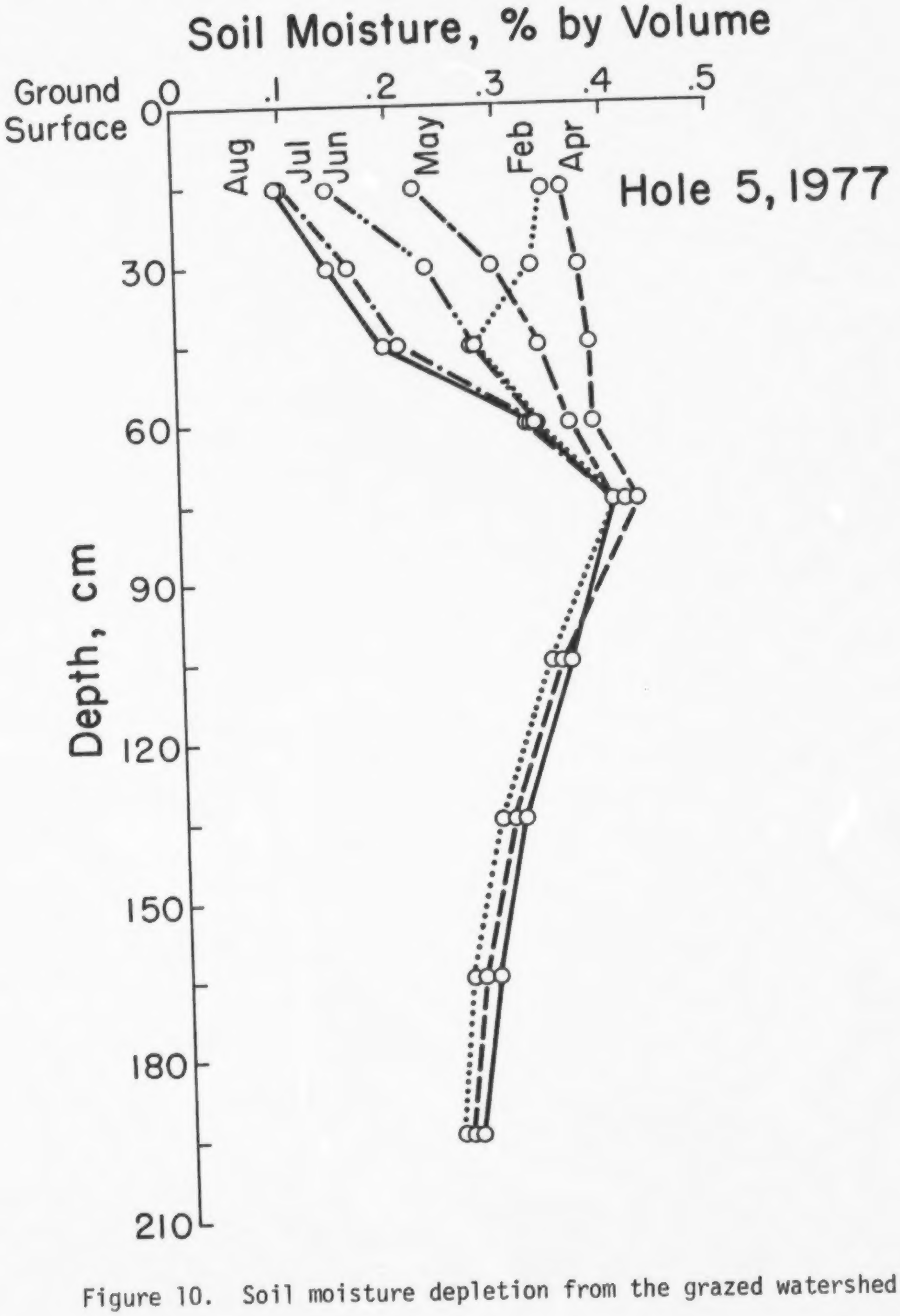


Figure 10. Soil moisture depletion from the grazed watershed.

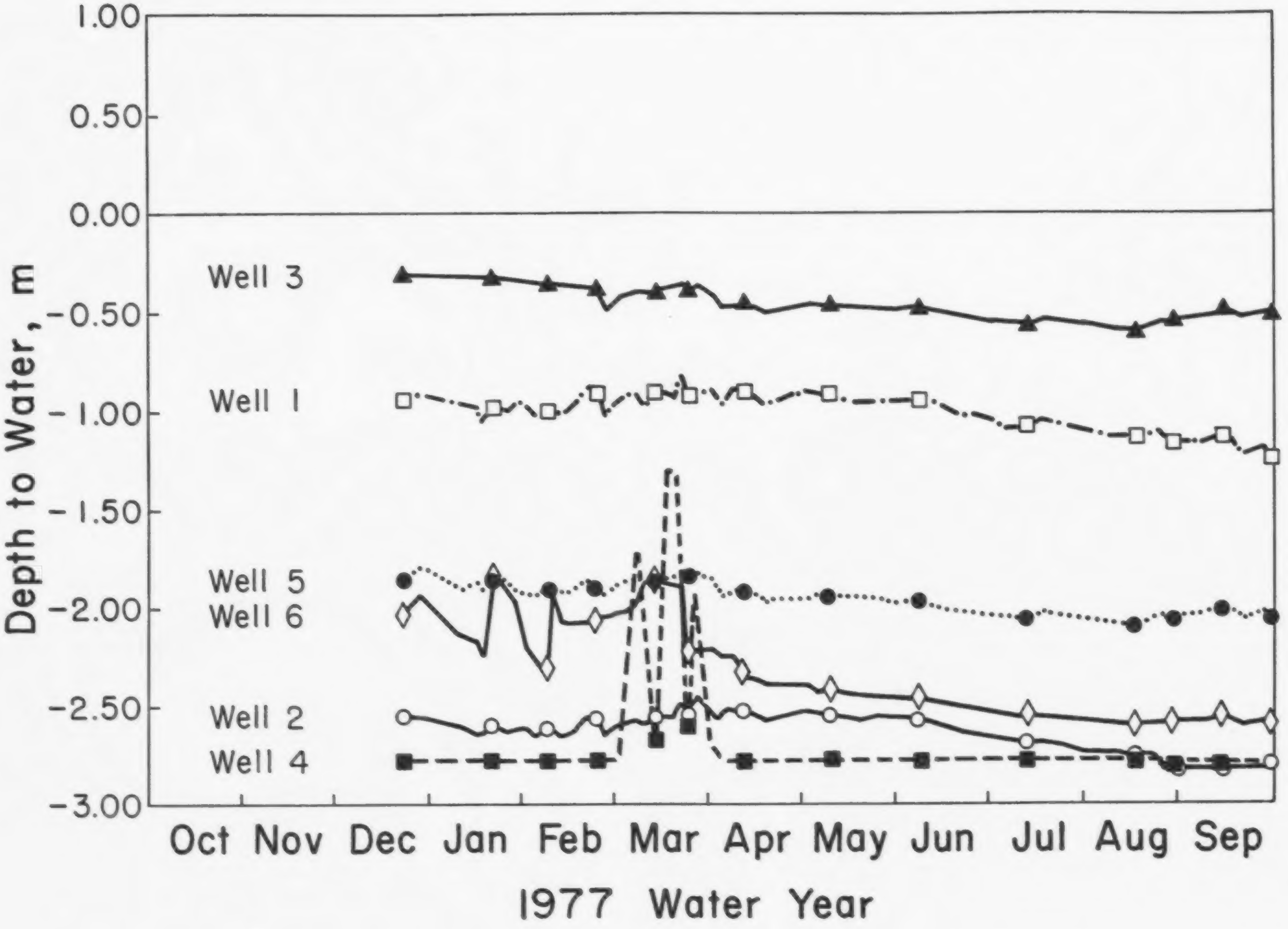


Figure 11. Rock Creek watershed groundwater levels, 1976-77.

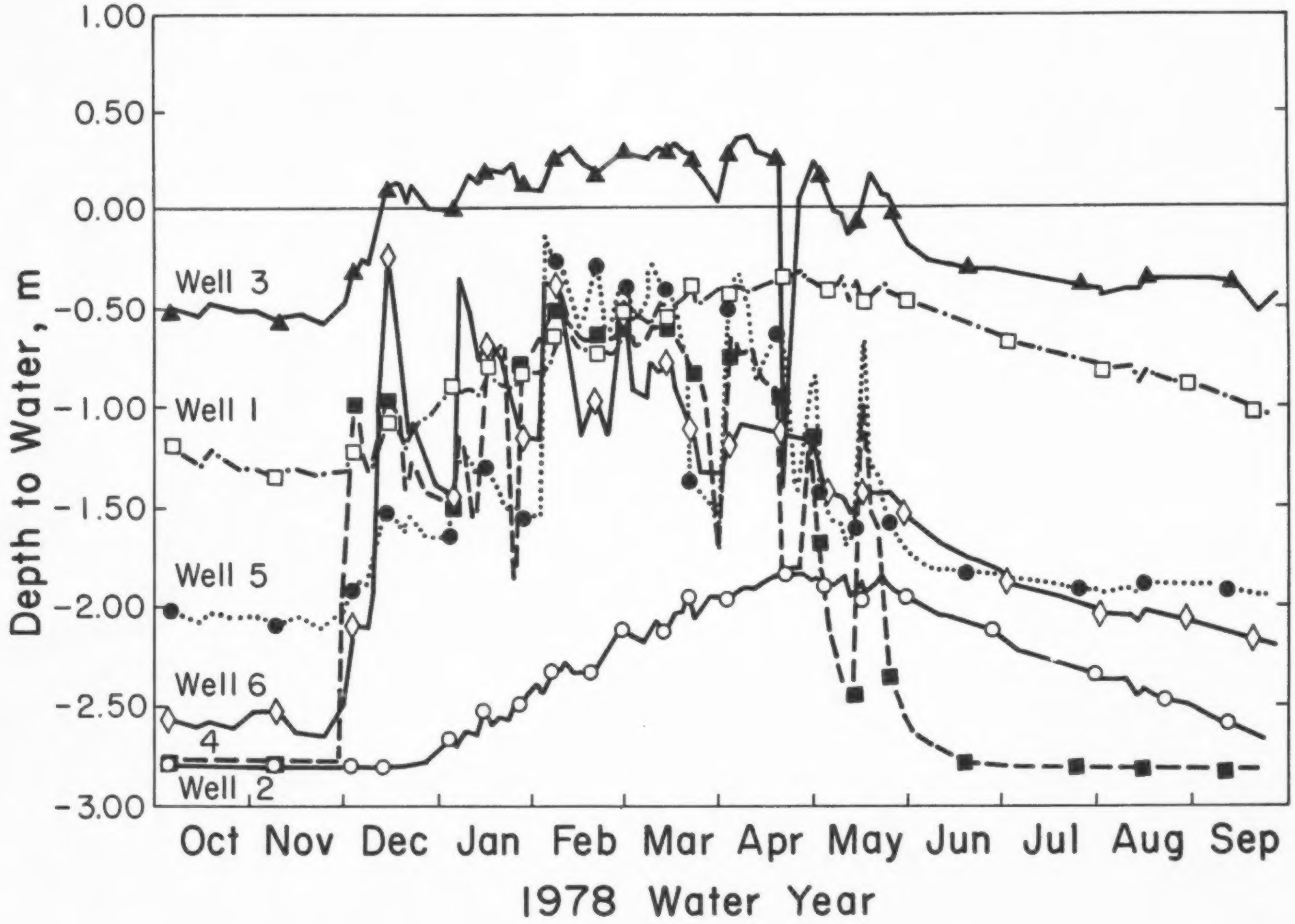


Figure 12. Rock Creek watershed groundwater levels,

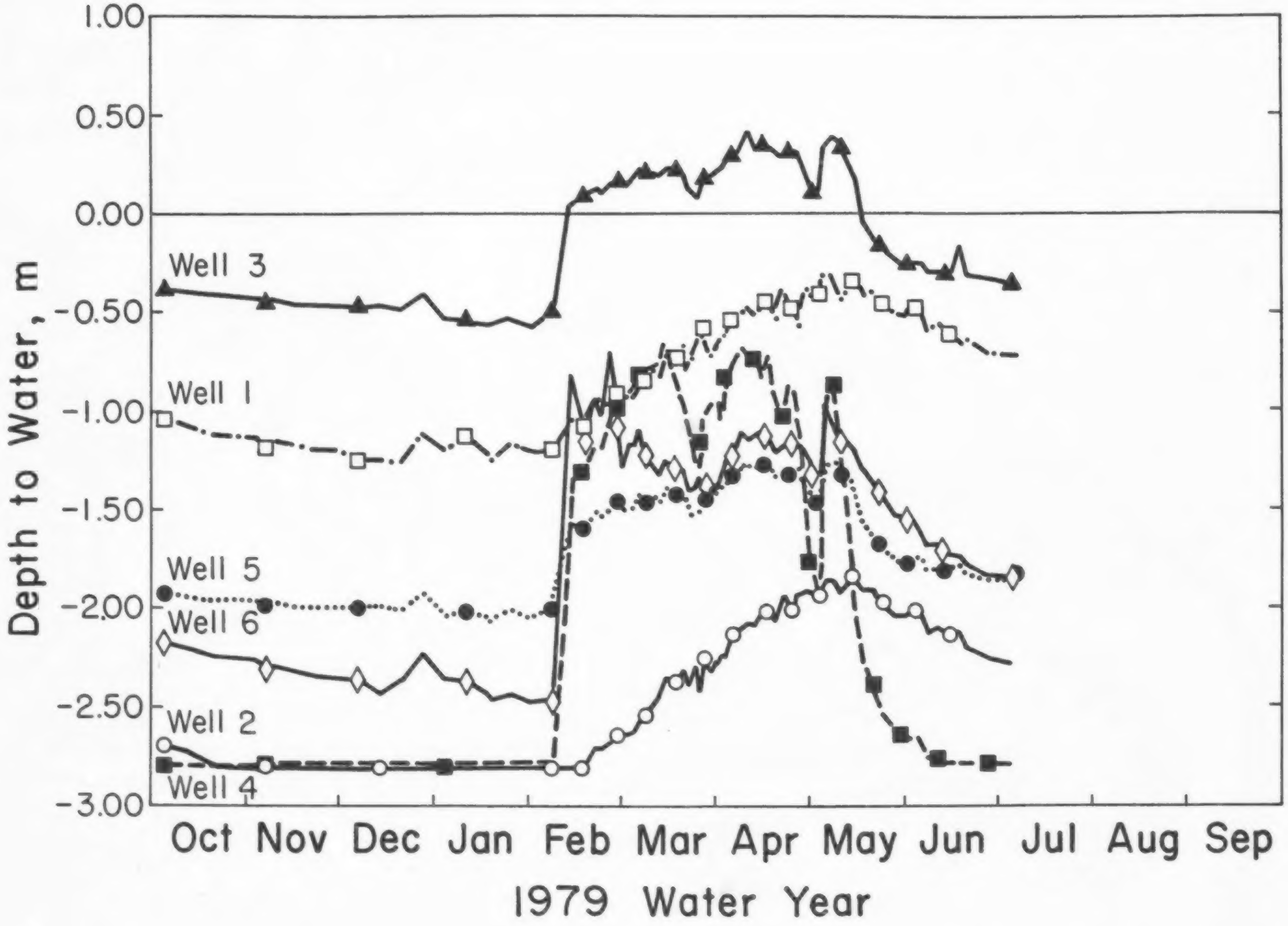


Figure 13. Rock Creek watershed groundwater levels, 1978-79.

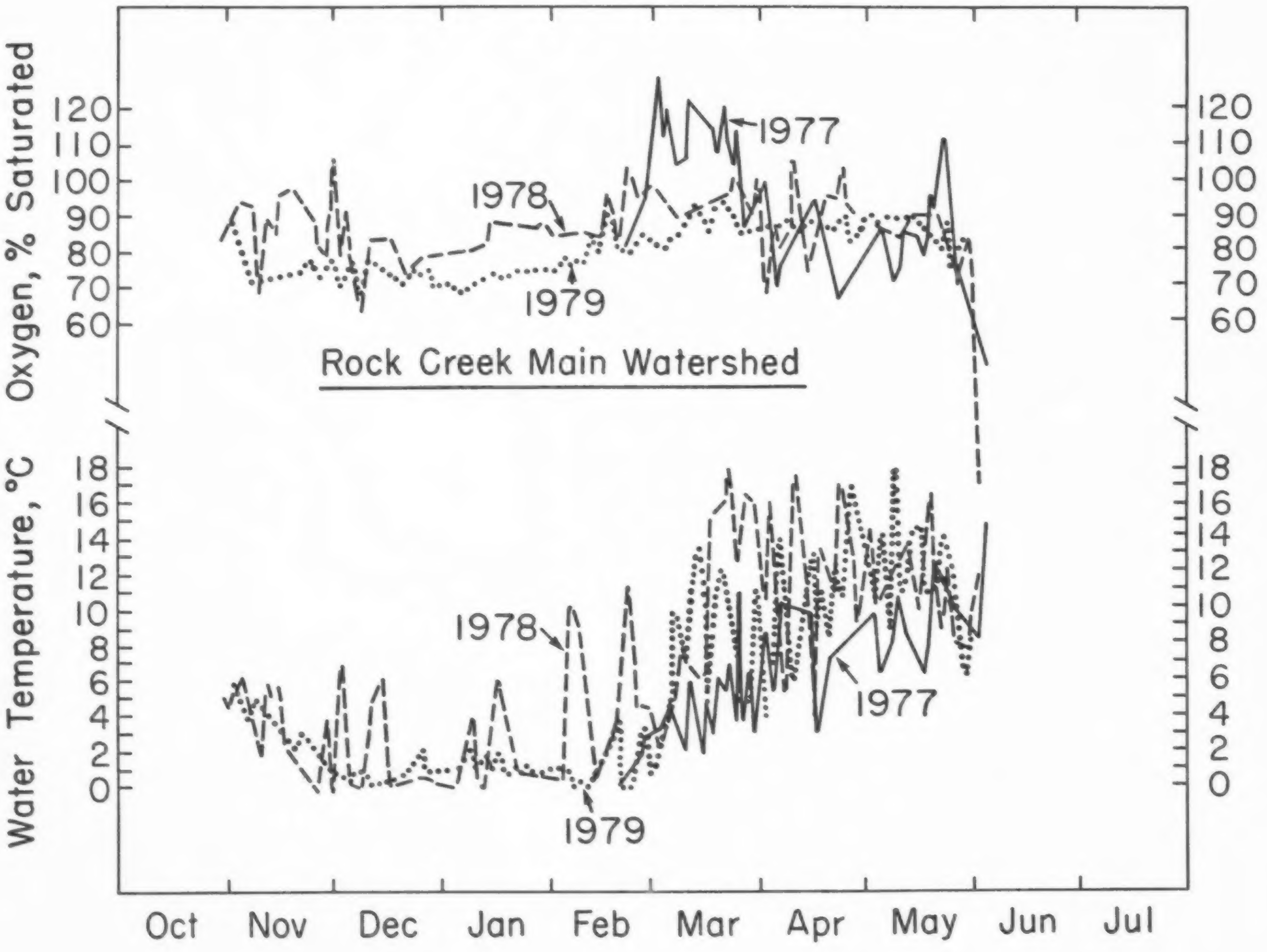


Figure 14. Water temperature and dissolved oxygen for the main watershed.

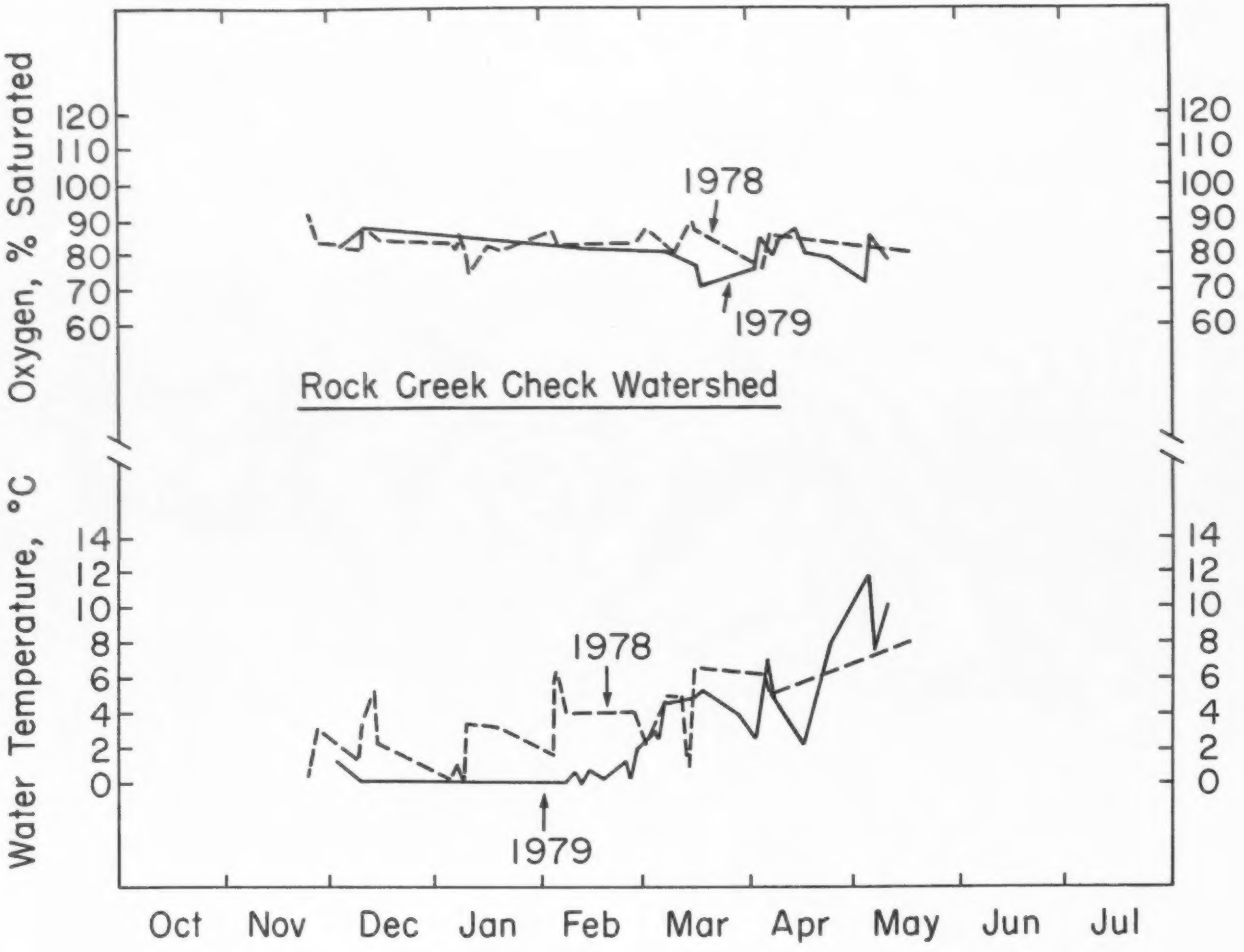


Figure 15. Water temperature and dissolved oxygen for the check watershed.

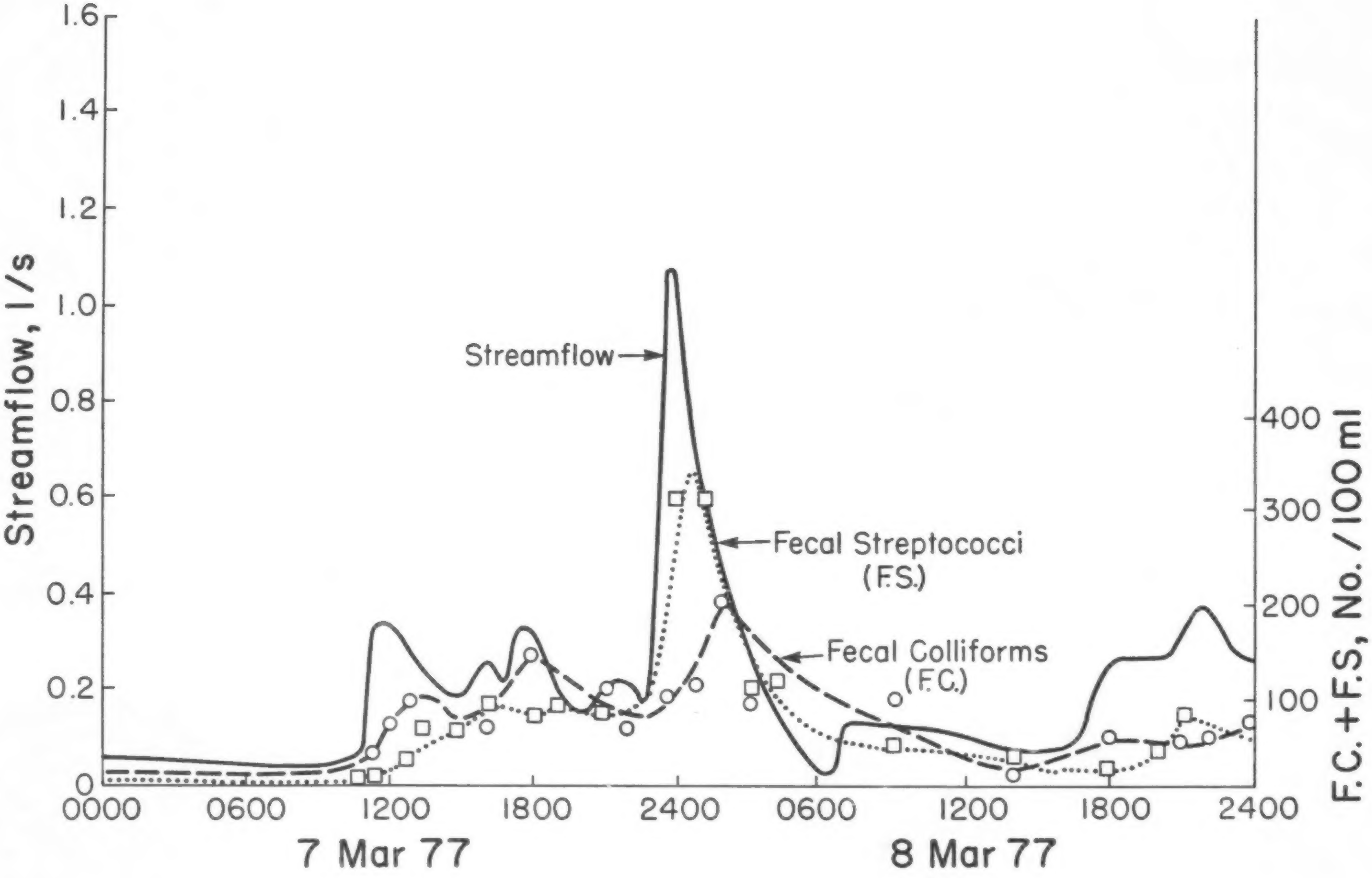


Figure 16. Streamflow hydrograph, fecal streptococci and coliform concentrations, Rock Creek main watershed.

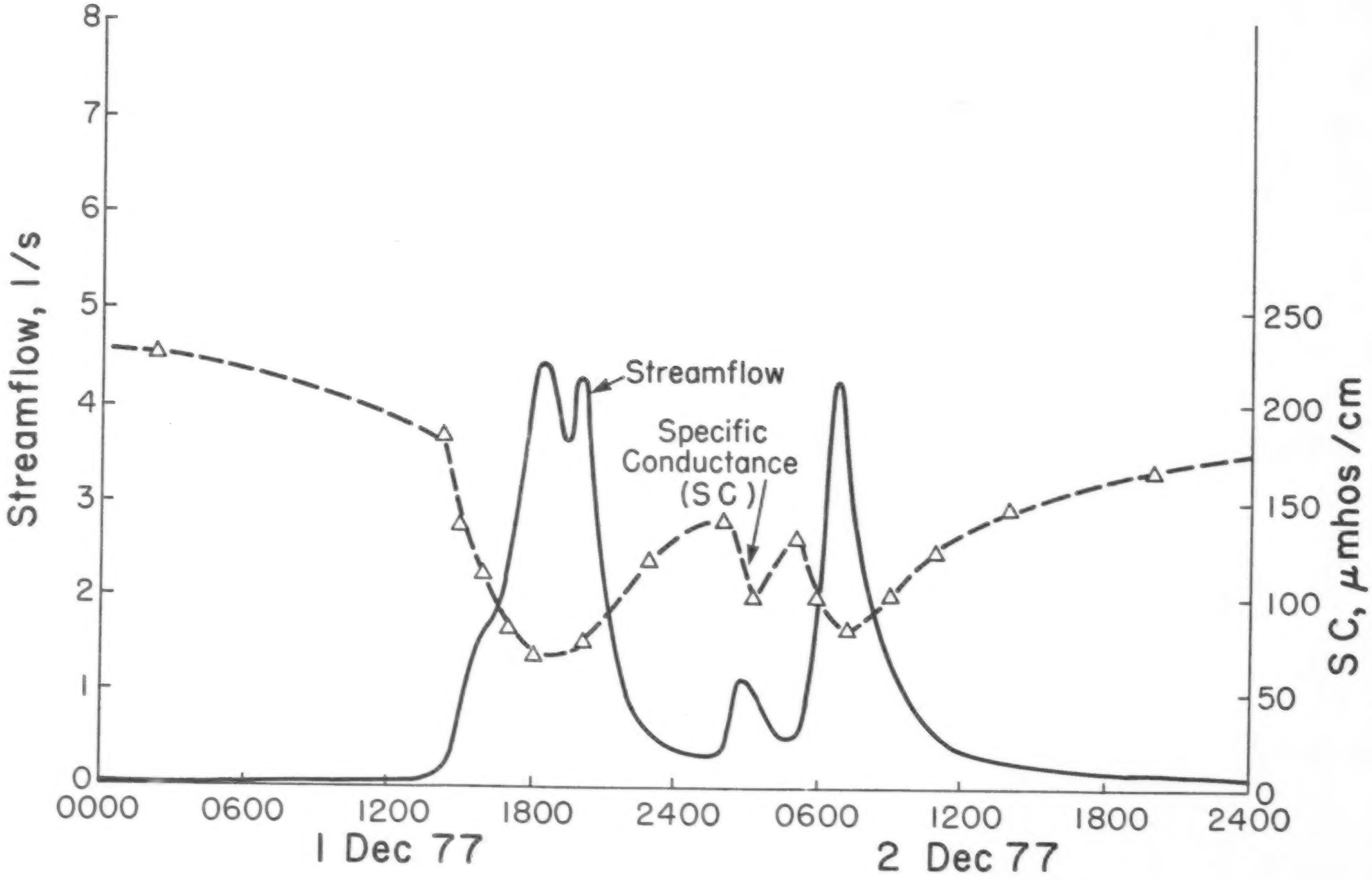


Figure 17. Streamflow hydrograph and specific conductivity, Rock Creek main watershed.

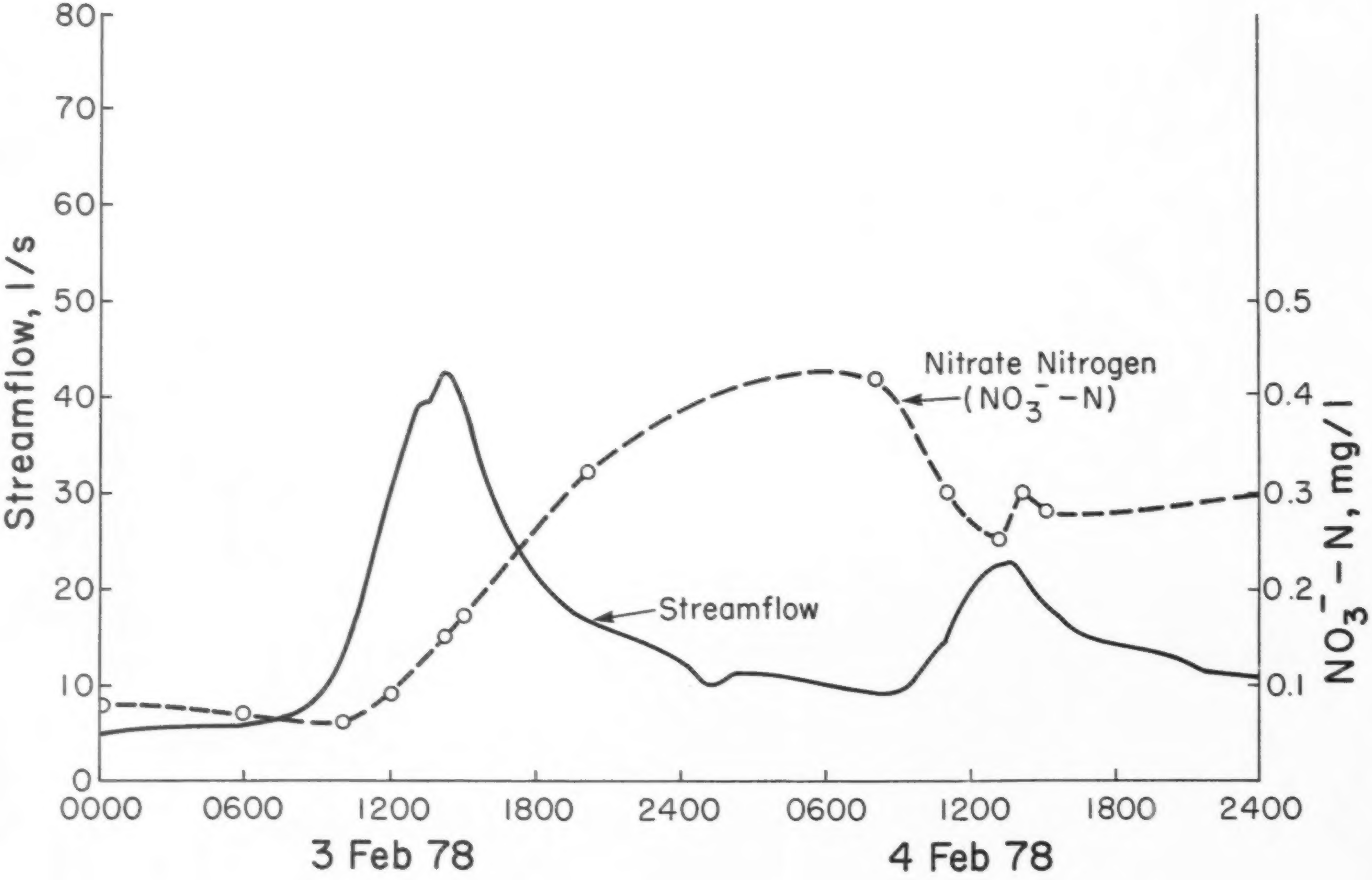


Figure 18. Streamflow hydrograph and nitrate concentrations, Rock Creek main watershed.

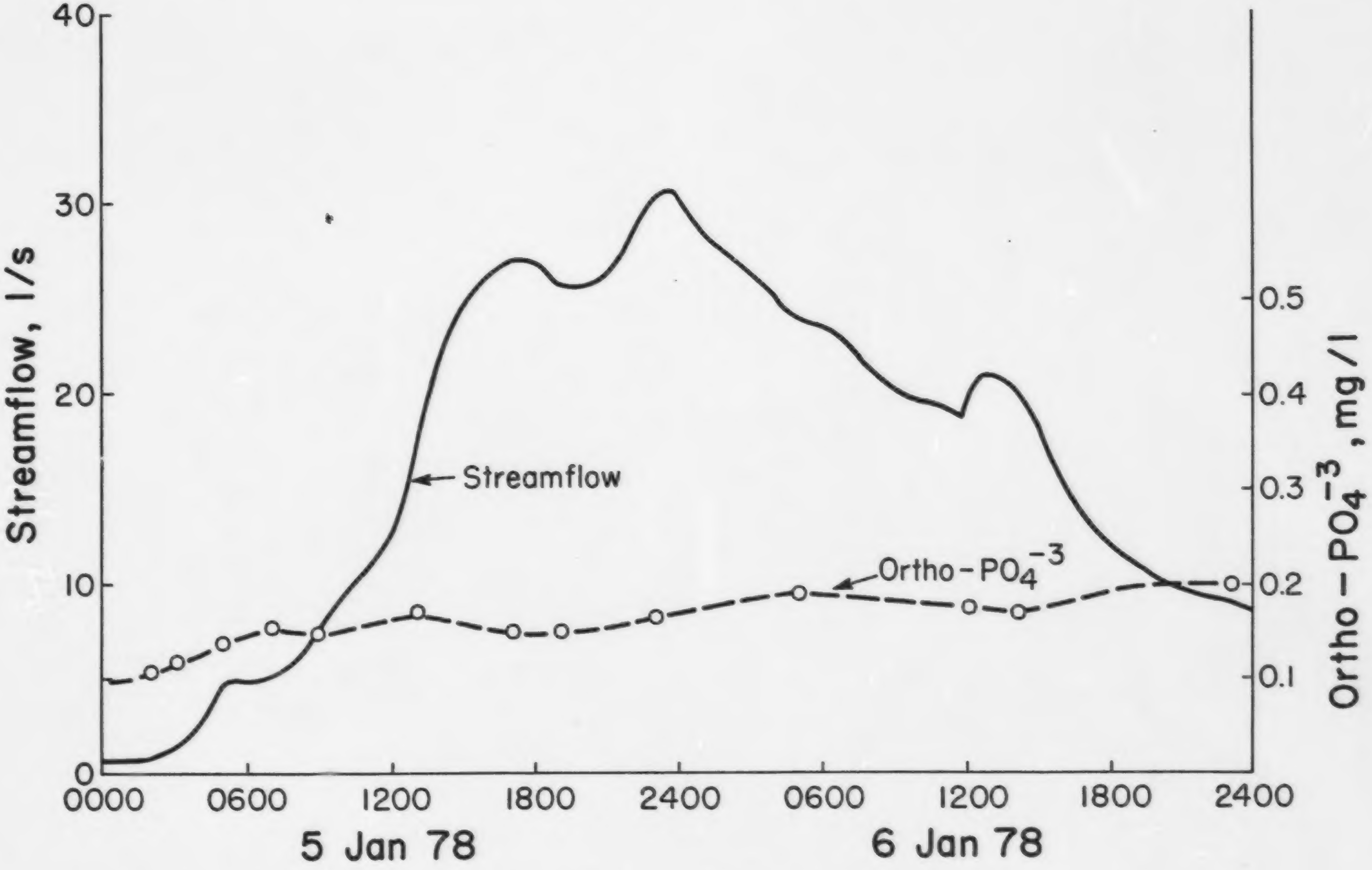


Figure 19. Streamflow hydrograph and ortho-phosphate concentrations, Rock Creek main watershed.

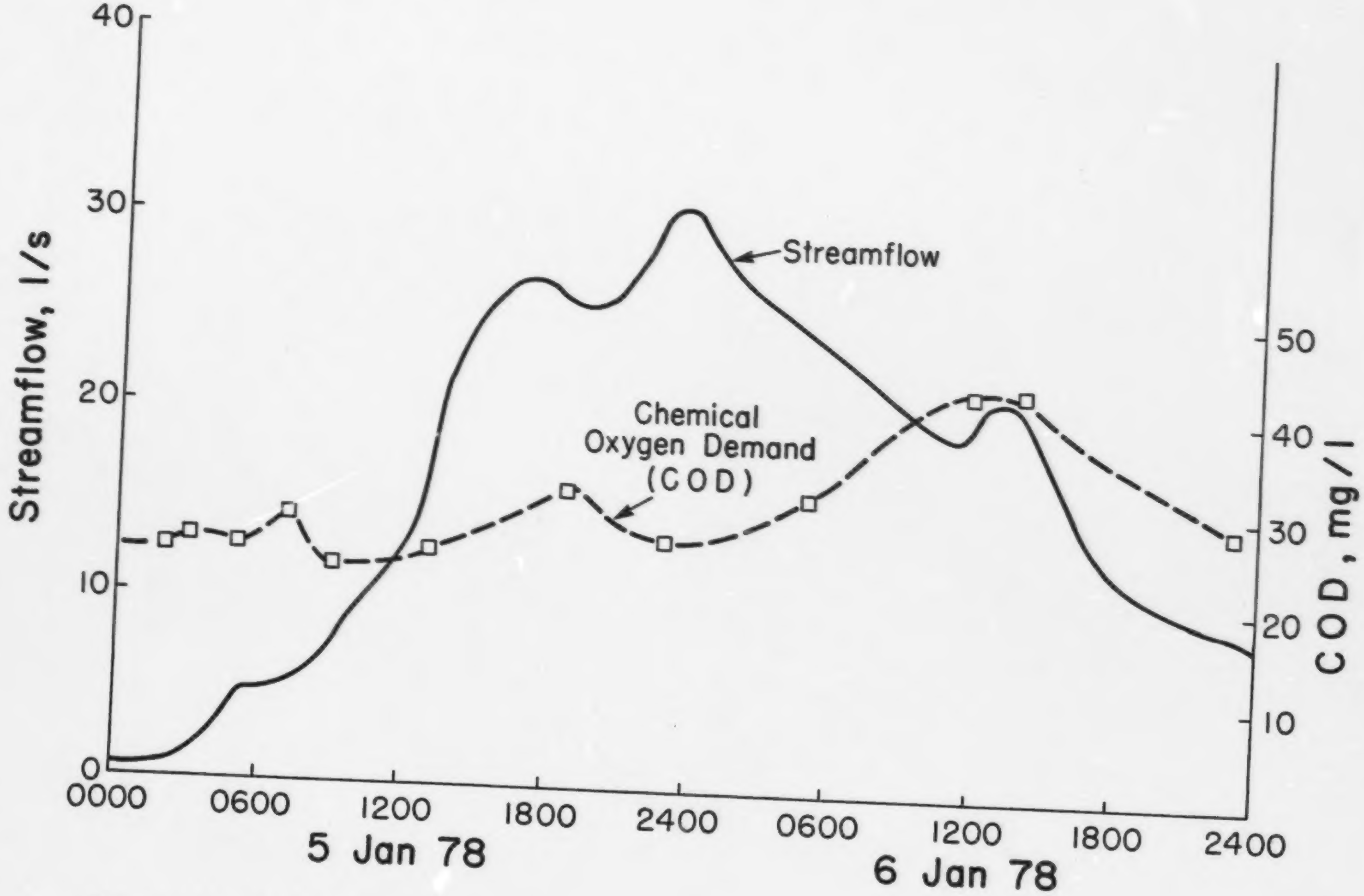


Figure 20. Typical water quality parameter concentration response, COD, to streamflow during snowmelt, Rock Creek main watershed.

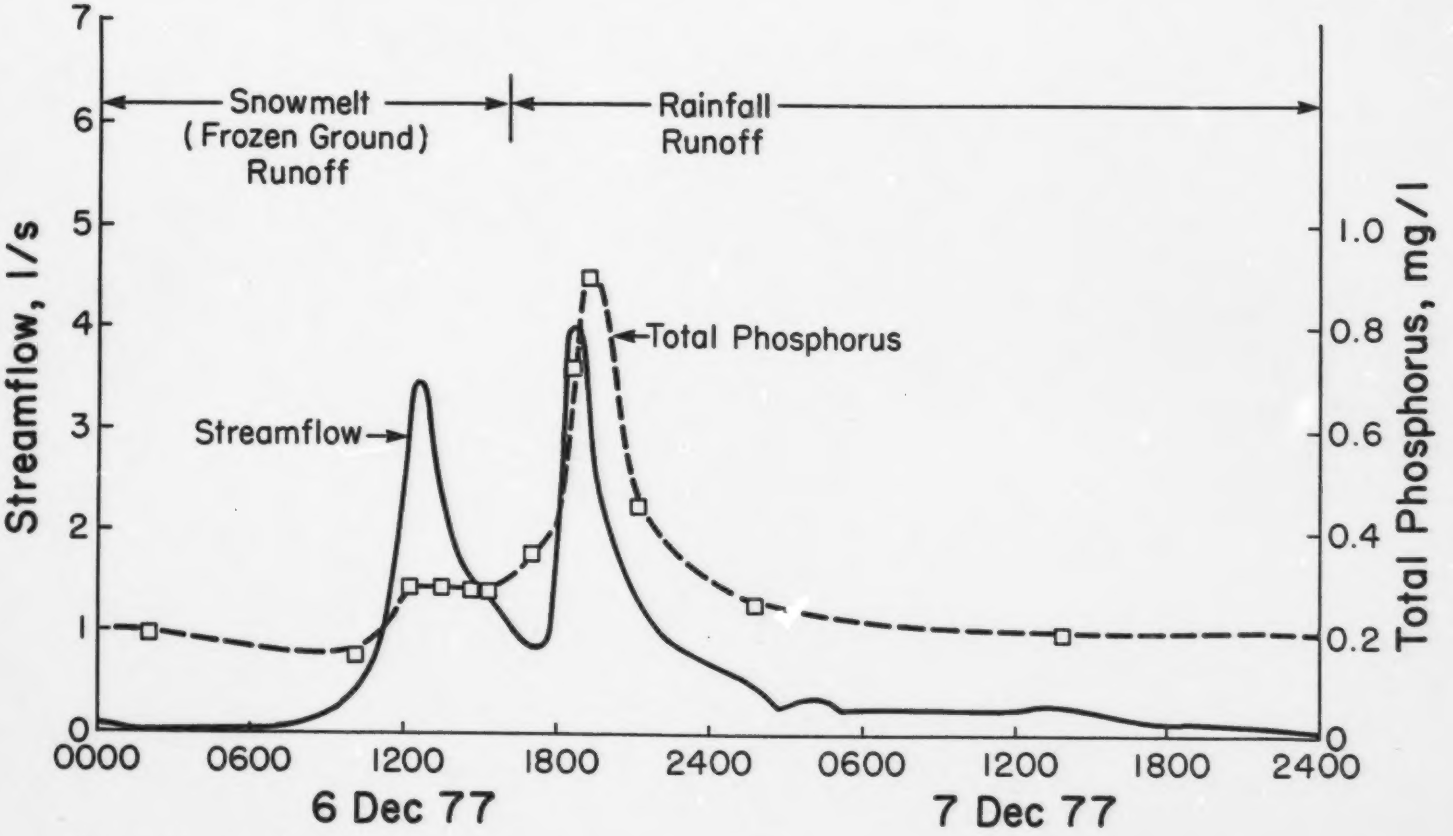
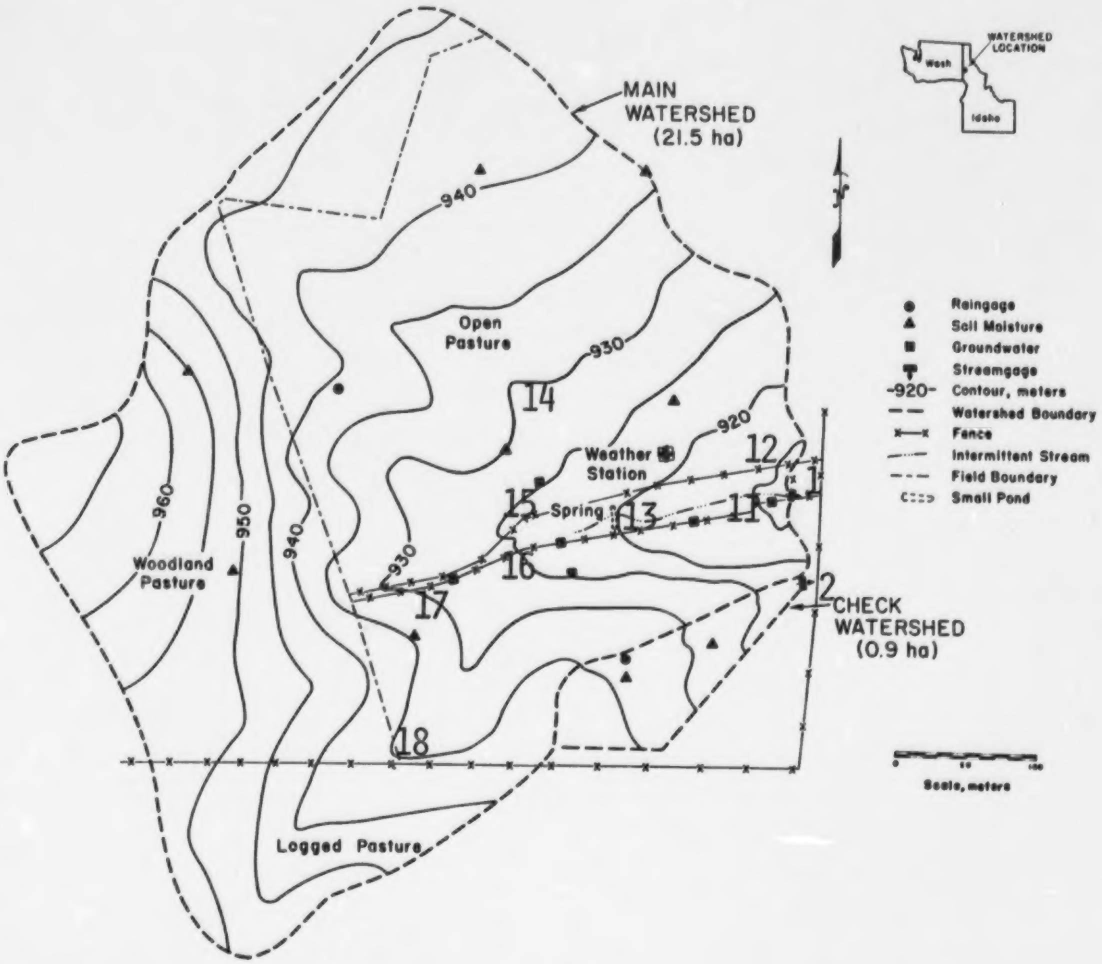


Figure 21. Typical water quality parameter response, total P, to streamflow during a mixed snowmelt and rainfall event, Rock Creek main watershed.


WATERSHED LOCATION
Wash
Idaho
MAIN WATERSHED (21.5 ha)
CHECK WATERSHED (0.9 ha)
Open Pasture
Woodland Pasture
Logged Pasture
Weather Station
Spring
940
930
920
960
950
1
2
11
12
13
14
15
16
17
18
● Raingage
▲ Soil Moisture
■ Groundwater
Streamgage
-920- Contour, meters
Watershed Boundary
Fence
Intermittent Stream
Field Boundary
Small Pond
0
50
100
Scale, meters

Site No.	Location	Runoff Area
1	Main station	Entire grazed watershed
2	Check station	Ungrazed watershed
11	Just south & above main stream channel weir pond	Southeast pasture
12	Just north & above main stream channel weir pond	Northeast pasture
13	Outlet of main stream channel pond	Woodland, no. & so. pasture
14	Large gulley channel in north pasture	North pasture
15	Above and north of pond	Northeast pasture
16	Above and south of pond	Southeast pasture
17	Main stream channel below woods	Woodland pasture
18	Upper southwest pasture	Logged pasture

Figure 22. Location and description of sampling sites within the watershed.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

REFERENCES

1. Asmussen, L. E., J. M. Sheridan, and C. V. Booram, Jr. Nutrient Movement in Streamflow from Agricultural Watersheds in the Georgia Coastal Plain. TRANSACTIONS of ASAE 22:809-815. 1979.

2. Buckhouse, J. C., and F. G. Gifford. Water Quality Implications of Cattle Grazing on a Semiarid Watershed in Southeastern Utah. J. Range Manage., 29:109-113. 1976.

3. Chichester, F. W., R. W. Van Keuren, and J. L. McGuinness. Hydrology and Chemical Quality of Flow from Small Pastured Watersheds. II. Chemical Quality. J. Environ. Qual., 8:167-171. 1979.

4. Doran, J. W., and D. M. Linn. Bacteriological Quality of Runoff water from Pastureland. Appli. Environ. Microbiol., 37:985-991. 1979.

5. Geldreich, E. E. Fecal Coliform and Fecal Streptococcus Density Relationships in Waste Discharges and Receiving Waters. Crit. Rev. Environ. Control, 6:349-369. 1976.

6. Geldreich, E. E. Current Status of Microbiological Water Quality Criteria. ASM News 47:23-27. 1981.

7. Hendricks, C. W. and S. M. Morrison. Multiplication and Growth of Selected Enteric Bacteria in Clear Mountain Stream Water. Pergammon Press, Great Britain. Water Res. 1:567-576. 1967.

8. Kibbey, H. J., C. Hagedorn, and E. L. McCoy. Use of Fecal Streptococci as Indicators of Pollution in Soil. Appl. and Environ. Microbiol. 35:711-717. 1978.

9. Kilmer, V.J., J. W. Gilliam, J. F. Lutz, R. T. Joyce, and C. D. Eklund. Nutrient Losses from Fertilized Grassed Watersheds in Western North Carolina. J. Environ. Qual., 3:214-219. 1974.

10. Kunkle, S. H. Concentrations and Cycles of Bacterial Indicators in Farm Surface Runoff. In: Proc. Cornell Waste Manage. Conf.. Syracuse, N.Y. Jan. 19-21, 1970. pp. 49-60.

11. Menzel, R. G., E. D. Rhoades, A. E. Olness, and S. J. Smith. Variability of Annual Nutrient and Sediment Discharges in Runoff from Oklahoma Cropland and Rangeland. J. Environ. Qual., 7:401-405. 1978.

12. Milne, C. M. Effect of a Livestock Wintering Operation on a Western Mountain Stream. Trans. Am. Soc. Agric. Eng., 19:749-752. 1976.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

13. Olness, A., S. J. Smith, E. D. Rhoades, and R. G. Menzel. Nutrient and Sediment Discharge from Agricultural Watersheds in Oklahoma. J. Environ. Qual., 4:331-336. 1975.

14. Olson, R. A., E. C. Seim, and J. Muir. Influence of Agricultural Practices on Water Quality in Nebraska: A Survey of Streams, Groundwater and Precipitation. Water Res. Bull., 9:301-311. 1973.

15. Robbins, J. W. D., D. H. Howells, and G. J. Kris. Stream Pollution from Animal Production Units. J. Water Pollut. Control Fed., 44:1536-1544. 1972.

16. Rycert, R. C., and G. R. Stephenson. Atypical *E. coli* in Streams. Appl. and Environmen. Microbiol. (In press). 1981.

17. Schepers, J. S., D. R. Anderson, G. E. Schuman, E. J. Vavricka, and H. D. Wittmuss. Agricultural Runoff in the Midwest. J. Water Poll. Control Fed. 44:1536-1544. 1980.

18. Schuman, G. D., and R. E. Burwell. Precipitation Nitrogen Contribution Relative to Surface Runoff Discharges. J. Environ. Qual., 3:366-368. 1974.

19. Skinner, Q. D., J. C. Adams, P. A. Richard, and A. A. Beetle. Effect of Summer Use of a Mountain Watershed on Bacterial Water Quality. J. Environ. Qual. 3:329-335. 1974.

20. Stephenson, G. R., and R. C. Rycert. Bottom Sediment: A Reservoir of *Escherichia coli* in Rangeland Streams. J. Range Manage. (In press). 1981.

21. Stephenson, G. R. and L. V. Street. Bacterial Variations in Streams from a Southwest Idaho Rangeland Watershed. J. Environ. Qual. 7:150-157. 1978.

22. Thomas, G. S., and J. D. Crutchfield. Nitrate-Nitrogen and Phosphorus Contents of Streams Draining Small Agricultural Watersheds in Kentucky. J. Environ. Qual. 3:46-49. 1974.

23. Timmons, D. R., and R. F. Holt. Nutrient Losses in Surface Runoff from a Native Prairie. J. of Environ. Qual. 6:369-373. 1977.

24. Timmons, D. R., E. W. Verry, R. E. Burwell, and R. F. Holt. Nutrient Transport in Surface Runoff and Interflow from an Aspens-Birch Forest. J. Environ. Qual. 6:188-192. 1977.

25. Van Donsel. D. J., E. E. Geldreich, and N. A. Clarke. Seasonal Variations in Survival of Indicator Bacteria in Soil and Their Contribution to Storm-Water Pollution. Appl. Microbiol. 15:1362-1370. 1967.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

APPENDIX A

Daily Observed Precipitation, Runoff, and Sediment Discharge

TABLE A-1. DAILY SUMMARY OF PRECIPITATION, RUNOFF, AND SEDIMENT DISCHARGE FOR ROCK CREEK MAIN WATERSHED

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	-------- Dec 76 --------			-------- Jan 77 --------			------ Feb 77 ------			---- Mar 77 ----		
Day	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1							.5			2.0	.032	.008
2				.5				.001		3/	.019	
3				1.5				.011			.019	
4				.5				.008			.016	
5								.009			.016	
6								.012			.018	
7								.018		11.0	.072	.119
8							1.0	.110	.152	7.0	.092	.120
9								.132	.159	8.0	.124	.125
10	1/			.5			.5	.198	.338		.016	.003
11	.5	.013		.5				.044	.018		.016	
12	.5	.006		4.0				.123		1.0	.018	
13		.007		1.0				.029		6.0	.005	
14		.001		4.0				.013		1.0	.015	
15		.002		1.0	.006			.018		1.0	.041	.011
16		.007		3.5	1.485	2.041		.019			.041	.007
17		.004		2/	2.372	4.649		.023		1.0	.026	.005
18				2.0	4.248	31.557		.021		3.0	.036	.005
19					.149	.266		.016		4.0	.068	.021
20					.075		1.0	.020		.5	.028	.006
21					.021		5.5	.039			.025	
22					.021		1.0	.034		.5	.016	
23	10.5			.5	.036			.013		1.0	.022	
24		.008			.014			.007		1.0	.013	
25	6.5	.007					2.5	.008			.009	
26	1.5	.202	.175					.025		1.0	.018	
27	.5	.547	.718				2.5	.025		8.0	.048	.022
28		.006					5.0	.086	.022		.026	.004
29											.013	
30											.008	
31				1.5				.010				
Total	20.00	0.810 (.735)5/	.893	21.0	8.427 (8.054)	38.513	19.5	1.062 (0.482)	.689	57.0	.926 (.404)	.456

1/Belfort weighing gage installed at weather station site.
2/Gage moved to mid-watershed site.
3/Wind shield added to gage.
4/Values accumulated where * appears due to clock stoppage.
5/Estimated surface runoff only.

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	---------- Apr 77----------			---------May 77--------			------Jun 77-------			----Jul 77------		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	.5	.011		3.0			6.0					
2		.008		11.5	.006	.006						
3		.006		3.0	.010	.006	1.5					
4		.004			.001		2.5					
5		.003								.5		
6												
7				1.5								
8				1.0			5.0					
9												
10				5.0	.008							
11					.002							
12	6.5						.5					
13		.020	.200				1.5					
14		.002		3.0	.002							
15	.5	.005					.5					
16	0.0	.008		1.0								
17				6.5	.010	.002				2.0		
18				12.5	.045	.032				8.5		
19				.5	.003					.5		
20				.5								
21												
22												
23				5.5	.005							
24				.5						1.5		
25										4.5		
26				8.5	.016	.016						
27				1.0	.001							
28				2.5	.005							
29												
30												
31												
Total	9.5	.067 (.018)	.200	67.0	.113 (.077)	.062	17.5	.001 (.001)		17.5		

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	Aug 77			Sep 77			Oct 77			Nov 77		
Day	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1										7.5	.017	.021
2				1.0						1.5	.003	
3				4.0								
4				1.5							.002	
5				.5						2.0	.008	
6							1.5				.003	
7							.5			1.0	.002	
8							.5				.107	5.279
9										3.0	.018	.006
10							.5				.016	
11											.004	
12							.5				.001	
13							.5			6.0	.028	.007
14										7.0	.050	.018
15										4.5	.037	.003
16				2.5							.006	
17				.5						2.5	.003	
18											.007	
19				6.0								
20												
21				2.5								
22	2.0									5.5		
23				3.5						10.5		
24	10.0			9.5						2.0		
25				2.0			7.0			15.5	1.170	.710
26	33.0	.001								.5	.076	.011
27				1.5			2.5			5.5	.077	.019
28	1.0			8.0						1.0	.036	.005
29	6.5			1.5			10.0			3.0	.048	.018
30	11.5			2.5			7.0	.004	.017		.010	
31							.5	.049	.084			
Total	64.0	.001 (.001)		47.0			31.0	.053 (.045)	.101	78.5	1.729 (1.599)	6.097

1977 Annual Totals: P = 340.0 mm; Q = 11.4 mm (9.8 mm): S = 40.8 Kg/ha.

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	Dec 77			Jan 78			Feb 78			Mar 78		
Day	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	15.0	.355	.385	1.0	.101	.004	5.0	.155	.007	.5	1.264	.225
2	7.0	.282	.359	1.5	.100	.003	4.0	.730	.134		.678	.283
3	5.0	.115	.117	10.5	.096	.003		6.750	17.909	1.0	.309	.076
4	.5	.049	.006	.5	.229	.019		5.363	3.431	3.5	.942	.482
5	.5	.010	.001	6.0	6.062	8.522		3.577	1.059	1.0	1.389	.357
6	6.5	.399	.874		7.498	10.996	13.0	8.015	11.104		.824	.104
7		.100	.016	.5	5.207	.560	11.5	7.450	25.531	3.0	.792	.110
8	5.0	.020	.001	5.0	6.614	9.265		4.491	1.796	8.0	2.652	2.152
9	.5	.032	.002	.5	4.638	1.438	1.5	2.586	.273	1.0	2.312	.534
10	7.5	.897	.763		2.013	.379		1.340	.093		1.266	.178
11	15.0	4.790	28.948	1.5	1.299	.128	3.5	.880	.030	1.5	.925	.104
12	2.5	1.336	.331	2.5	1.196	.102		.750	.073	2.5	1.345	.208
13	*	12.040	220.001	1.0	.863	.127		.469	.052	5.5	1.483	.397
14	32.5*	7.167	86.672	1.0	1.644	.234	.5	.500	.052	4.5	1.141	.181
15	13.0	5.009	31.787	2.5	1.920	.590	4.5	.375	.019	.5	1.391	1.081
16	2.0	2.231	.488	2.0	1.927	.192		.423	.024		.852	.128
17	6.5	1.143	.168	2.5	1.589	.138		.452	.115		.504	.031
18	3.5	.825	.067	1.0	1.208	.076	1.5	.628	.083		.275	.025
19		.544	.035	1.0	.896	.066	.5	.851	.044		.186	.028
20		.293	.027	2.5	1.371	.117	.5	.580	.036		.136	.020
21		.274	.020	1.5	.960	.073		.354	.008		.107	.016
22	.5	.276	.019	.5	.619	.039		.244	.011		.088	.017
23	2.0	.241	.010	.5	.278	.018	1.0	.322	.025	3.5	.184	.130
24	.5	.180	.008		.127	.007	2.0	.326	.027	.5	.122	.017
25		.161	.006	2.5	.154	.013	4.0	.859	.106	.5	.080	.009
26	.5	.149	.006	5.0	.159	.011	5.0	1.428	.297		.060	.008
27		.110	.004		.169	.012	5.0	1.543	.256		.039	.005
28		.115	.003	7.0	.161	.011	4.0	1.681	.390		.028	.003
29	3.0	.149	.006	1.0	.179	.019					.022	.002
30	11.5	.216	.006	1.0	.161	.010					.024	.002
31		.143	.004	4.5	.122	.006				3.0	.026	.037
Total	143.5	39.651 (36.832)	371.140	66.5	49.560 (35.560)	33.168	67.0	53.122 (43.289)	62.985	40.0	21.446 (6.059)	6.950

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	Apr 78			May 78			Jun 78			Jul 78		
Day	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	19.0	1.933	2.604		.033	.002				*		
2	3.0	1.053	.269		.026	.001				*		
3	1.0	.438	.053	1.5	.021					*		
4	4.0	.592	.189	1.5	.022	.001				19.0*	.029	.014
5	2.0	.724	.139		.021	.001						
6	1.0	.501	.080		.011	.001						
7	*	1.820	1.341		.006							
8	*	.930	.120		.004							
9	*	.342	.288	3.0	.017	.001				1.5		
10	*	.127	.013	1.0	.011	.001				.5		
11	*	.083	.008	1.0	.009							
12	7.0*	.061	.004	1.0	.006							
13		.051	.004	1.5	.017	.001	4.0					
14	1.0	.058	.008	2.5	.019	.001						
15	.5	.053	.004	10.0	.107	.072				*		
16	11.0	.571	.655	11.0	.418	.769				5.0*		
17	1.0	.153	.016		.167	.017						
18		.054	.004		.043	.003						
19		.033	.002		.017							
20	2.0	.100	.015		.006							
21		.042	.002	9.5	.051	.083						
22	2.5	.050	.006	.5	.036	.005						
23		.041	.002	.5	.009		*					
24		.020	.001	2.0	.018	.001	*					
25		.016			.006		*	.006	.003			
26	4.0	.026	.006	.5	.004	.001	13.0*					
27	11.0	.288	.489	2.5	.017	.003						
28	3.0	.487	.121	.5	.008	.001	1.0					
29		.130	.013									
30		.051	.004									
Total	73.0	10.028 (4.491)	6.460	50.0	1.130 (.687)	.965	18.0	.006 (.006)	.003	26.0	.029 (.029)	.014

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Aug 78			Sep 78			Oct 78			Nov 78		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1							0.5					
2												
3										4.5		
4				.5						3.5	.004	.006
5				*							.002	
6				*							.003	
7				*								
8				*								
9				*								
10				*								
11				25.5*								
12	*											
13	12.0*			*								
14				*								
15	13.0			*								
16				*						2.5		
17				*						5.5	.028	.012
18				*						7.5	.004	
19	.5			*						11.+	.006	.001
20	3.0			1.0*						*	.006	
21	1.0			1.0						*	.008	
22	*						.5			2.0*	.009	
23	17.5*										.012	
24											.012	
25											.012	
26											.009	
27										10.0	.010	
28				1.5						2.5	.012	
29							.5			1.5	.010	
30	5.0						.5			16.0	.034	.002
31	1.0											
Total	53.0			29.5			2.0			66.5	.181 (.048)	.021

1978 Annual Totals: P = 676.0 mm: Q = 177.6 mm (118.6 mm); S = 487.9 Kg/ha.

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Dec 78			Jan 79			Feb 79			Mar 79		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	8.5	.032	.002	*				.016	.002		1.514	.165
2	9.5	.018		*				.035	.007		.971	.134
3		.031	.002	5.0*			4.0	.012		1.0	.614	.135
4	13.0	.188	.023				.5	.010		6.0	3.233	1.106
5		.024	.001					.031	.003	5.5	5.898	2.849
6		.016	.001				7.0	.035	.010	.5	5.993	2.611
7		.013					3.5	.204	.056	2.0	5.610	2.259
8	.5	.012					.5	.041	.003		2.368	.468
9	4.5	.012					4.0	.296	.115		1.144	.172
10	4.0	.013		7.0			16.0	1.771	2.819		.723	.092
11	16.0	.449	.095	2.5			7.0	5.983	5.098		.635	.075
12	.5	.028	.001	3.0			31.0	17.370	116.523		.667	.070
13	.5	.015		.5			4.5	28.246	424.354		.515	.070
14		.013		4.0				4.567	2.700		.427	.057
15		.014		5.5				1.701	.626	3.0	.543	.104
16		.013		*	.012		2.5	1.081	.256	9.0	2.483	.662
17	2.0	.010		.5*	.012		2.0	1.081	.328		1.277	.150
18	6.0	.012			.011		4.0	2.732	.580		.656	.083
19	*	.012		.5	.008		3.0	1.994	.279		.366	.040
20	2.0*	.012		2.5	.011		1.0	1.108	.176	.5	.223	.027
21		.018		15.0	.015		2.5	.733	.051		.146	.018
22		.021		*	.012		.5	.731	.086		.074	.008
23	6.0	.050	.012	*	.012		5.5	.359	.030		.044	.005
24		.268	.036	6.0*	.011		2.0	.606	.126		.025	.003
25	.5	.032	.001		.008		7.0	8.351	13.046		.020	.002
26		.013		1.0	.008		4.5	7.982	3.429	1.0	.028	.002
27	2.5	.012		2.5	.008		9.0	3.839	.952	14.5	1.104	1.148
28	*	.012		.5	.008		1.5	3.135	.667	3.0	1.371	.242
29	*	.012			.009					.5	.705	.103
30	*				.008					2.0	.379	.046
31	*				.010					2.0	.390	.046
Total	76.0	1.375	.174	56.0	.163 (.0)		123.0	94.050 (82.755)	572.322	50.5	40.146 (25.186)	12.953

TABLE A-1 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Apr 79			May 79			Jun 79			Jul 79		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	1.5	.496	.055	2.5	.128	.024				8.5		
2	9.0	1.740	.891	.5	.122	.005				.5		
3	*	1.592	.172		.069	.001						
4	.5*	1.325	.154	15.0	.610	.326				1.0		
5		.707	.082	22.5	9.009	12.110				1/		
6	12.0	3.882	6.512		4.702	.838	1.0					
7	.5	2.291	.406		1.803	.150						
8	3.0	1.321	.210	4.0	1.144	.143						
9	5.0	2.752	1.070		.992	.062						
10	.5	1.426	.178		.422	.013						
11		1.011	.110		.210	.003	1.0					
12	7.5	1.166	2.735		.143	.002						
13	.5	1.975	1.668		.104	.002	.5					
14	.5	.891	.082		.083	.001						
15		.694	.075		.071	.001						
16	7.0	.853	.872		.050	.001	2.0					
17	3.0	2.085	1.509		.036		16.0					
18		.767	.055		.032		1.5					
19		.516	.021		.025							
20	.5	.395	.017		.021							
21		.255	.010		.014							
22	.5	.283	.015		.009							
23	5.0	.708	.146	1.0	.029	.001						
24	8.0	2.109	1.818		.040	.001						
25		.843	.090		.019							
26		.395	.032		.011		1.0					
27		.217	.013	.5								
28		.142	.006	.5								
29		.111	.004		.015							
30	1.0	.122	.005		.016		1.0					
31	65.0	33.070	19.013	46.5	19.929	13.720	24.0			10.0		
		(12.147)			(14.650)							

1/Gage shut down (7/5) and removed from site.
1979 Annual Totals: P = 520.0 mm; Q = 188.9 mm (135.7 mm); S = 618.1 Kg/ha

TABLE A-2. DAILY PRECIPITATION, RUNOFF, AND SEDIMENT DISCHARGE FOR ROCK CREEK CHECK WATERSHED

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Dec 76			Jan 77			Feb 77			Mar 77		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1							.5			2.0		
2				.5						3/		
3				1.5								
4				.5								
5												
6								.094	.062			
7								.082	.056	11.0	.019	
8							1.0	.544	.673	7.0	.068	
9								.442	.314	8.0	.223	
10	1/			.5			.5	.362	.352			
11	.5			.5								
12	.5			4.0						1.0		
13				1.0						6.0		
14				4.0						1.0		
15				1.0	.325					1.0		
16				3.5	5.020	1.028						
17				2/	4.735	.763				1.0		
18				2.0	12.704	8.479				3.0		
19					.022					4.0		
20					.084		1.0			.5		
21							5.5					
22							1.0			.5		
23	10.5			.5						1.0		
24										1.0		
25	6.5						2.5					
26	1.5	4.144	1.937							1.0		
27	.5	4.990	2.476				2.5			8.0		
28							5.0					
29												
30												
31				1.5								
Total	20.0	9.134	4.413	21.0	22.890	10.270	19.5	1.524	1.457	57.0		.310

[1] Belfort weighing gage installed at weather station site.
[2] Gage moved to mid-watershed site.
[3] Wind shield added to gage.

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Apr 77			May 77			Jun 77			Jul 77		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	0.5			3.0			6.0					
2				11.5								
3				3.0			1.5					
4							2.5					
5										.5		
6												
7				1.5								
8				1.0			5.0					
9												
10				5.0								
11												
12	6.5						.5					
13							1.5					
14				3.0								
15	.5						.5					
16	2.0			1.0								
17				6.5						2.0		
18				12.5						8.5		
19				.5						.5		
20				.5								
21												
22												
23				5.5								
24				.5						1.5		
25										4.5		
26				8.5								
27				1.0								
28				2.5								
29												
30												
31												
Total	9.5			67.0			17.5			17.5		

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	--------- Aug 77---------			--------- Sep 77--------								
Day	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1				1.0								
2				4.0								
3				1.5								
4				.5								
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16				2.5								
17				.5								
18												
19				6.0								
20												
21				2.5								
22	2.0											
23				3.5								
24	10.0			9.5								
25				2.0								
26	33.0	.023										
27				1.5								
28	1.0			8.0								
29	6.5			1.5								
30	11.5			2.5								
31												
31												
Total	64.0	.023		47.0								

1977 Annual Totals: P = 340.0 mm; Q = 33.9 mm; S = 16.1 Kg/ha.

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Oct 77			Nov 77			Dec 77			Jan 78		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1				7.5			15.0	1.003	1.019	1.0		
2				1.5			7.0	.595	.672	1.5		
3							5.0	.077	.837	10.5		
4							.5			.5		
5				2.0			.5			6.0	3.704	1.082
6	1.5						6.5	.441	.493		2.139	.361
7	.5			1.0						.5	.298	.035
8	.5						5.0			5.0	2.789	.678
9				3.0			.5			.5	.915	.135
10	.5						7.5	.948	.558		.132	.013
11							15.0	3.010	3.395	1.5		
12	.5						2.5	.232	.099	2.5		
13	.5			6.0			*1/	6.262	5.032	1.0		
14				7.0			32.5*	3.054	2.484	1.0	.154	.035
15				4.5			13.0	2.062	1.184	2.5	.242	.107
16							2.0	.198	.028	2.0	.276	.051
17				2.5			6.5			2.5		
18							3.5			1.0		
19										1.0		
20										2.5	.110	.025
21							.5			1.5		
22				5.5			2.0			.5		
23				10.5			.5			.5		
24				2.0								
25	7.0			15.5	1.499	.883	.5			2.5		
26				.5	.011	.012				5.0		
27	2.5			5.5	.123	.094						
28				1.0			3.0			7.0		
29	10.0			3.0			11.5			1.0		
30	7.0						3.0			1.0		
31	.5									4.5		
Total	31.0			78.5	1.633	.989	143.5	17.882	15.801	66.5	10.759	2.522

1/Values accumulated where * appears due to clock stoppage.

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Feb 78 P	Feb 78 Q	Feb 78 S	Mar 78 P	Mar 78 Q	Mar 78 S	Apr 78 P	Apr 78 Q	Apr 78 S	May 78 P	May 78 Q	May 78 S
1	5.0			.5	.121	.018	19.0	1.433	1.259			
2	4.0	.694	.324				3.0	.132	.064			
3		3.451	1.380	1.0			1.0			1.5		
4		.353	.062	3.5	.088	.029	4.0	.132	.056	1.5		
5		.110	.046	1.0	.121	.038	2.0	.099	.044			
6	13.0	2.051	1.326				1.0					
7	11.5	2.348	1.624	3.0			*	.805	.241			
8		.331	.064	8.0	.838	.416	*					
9	1.5	.110	.028	1.0	.209	.060	*			3.0		
10							*			1.0		
11	3.5			1.5			*			1.0		
12				2.5	.110	.023	7.0*			1.0		
13				5.5	.309	.070				1.5		
14	.5			4.5			1.0			2.5		
15	4.5			.5	.209	.070	.5			10.0		
16							11.0	.276	.160	11.0	.650	.518
17							1.0					
18	1.5	.044	.013									
19	.5											
20	.5						2.0					
21										9.5		
22							2.5			.5		
23	1.0			3.5						.5		
24	2.0			.5						2.0		
25	4.0	.055	.012	.5								
26	5.0	.265	.069				4.0			.5		
27	5.0	.198	.025				11.0	.154	.087	2.5		
28	4.0	.198	.032				3.0	.331	.178	.5		
29												
30												
31				3.0								
Total	67.0	10.208	5.005	40.0	2.005	.724	73.0	3.362	2.089	50.0	.650	.518

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Jun 78 P	Jun 78 Q	Jun 78 S	Jul 78 P	Jul 78 Q	Jul 78 S	Aug 78 P	Aug 78 Q	Aug 78 S	Sep 78 P	Sep 78 Q	Sep 78 S
1				*								
2				*								
3				*								
4				19.0*						.5		
5										*		
6										*		
7										*		
8										*		
9				1.5						*		
10				.5						*		
11										22.5*		
12							*					
13	4.0						12.0*			*		
14										*		
15				*			13.0			*		
16				5.0*						*		
17										*		
18										*		
19							.5			*		
20							3.0			*		
21							1.0			1.0*		
22							*			1.0		
23	*						17.5*					
24	*											
25	*											
26	13.0*											
27												
28	1.0											
29										1.5		
30							5.0					
31							1.0					
Total	18.0			26.0			53.0			29.5		

1978 Annual Totals: P = 676.0 mm; Q = 46.5 mm; S = 27.6 Kg/ha.

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	--------- Oct 78---------			---------Nov 78-------			------Dec 78-------			----Jan 79------		
Day	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1	0.5						8.5			*		
2							9.5			*		
3				4.5				.196	.086	5.0*		
4				3.5			13.0	.923	.140			
5												
6												
7												
8							.5					
9							4.5					
10							4.0			7.0		
11							16.0	2.082	1.639	2.5		
12							.5			3.0		
13							.5			.5		
14										4.0		
15										5.5		
16				2.5						*		
17				5.5			2.0			.5*		
18				7.5			6.0					
19				11.4			*			.5		
20				*			2.0*			2.5		
21				*						15.0		
22				2.0*						*		
23							6.0	.205	.256	*		
24								1.011	.129	6.0*		
25							.5					
26										1.0		
27				10.0			2.5			2.5		
28				2.5			*			0.5		
29	.5			1.5			*					
30	.5			16.0			*					
31							*					
Total	2.0			66.5			76.0	4.417	2.250	56.0		

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

Day	Feb 79			Mar 79			Apr 79			May 79		
	P	Q	S	P	Q	S	P	Q	S	P	Q	S
1							1.5			2.5		
2					.064	.009	9.0	.132	.042	.5		
3	4.0			1.0			*	.375	.244			
4	.5			6.0	.717	.168	.5 *	.010	.002	15.0	.058	.058
5				5.5	.805	.097				22.5	4.195	3.247
6	7.0	.015	.014	.5	.111	.009	12.0	1.300	.933		.579	.143
7	3.5	.310	.131	2.0	.108	.024	.5	.020	.006			
8	.5						3.0			4.0		
9	4.0	.607	.268				5.0	.340	.242			
10	16.0	1.949	.364				.5					
11	7.0	2.679	.355									
12	31.0	6.184	.700				7.5	.163	.241			
13	4.5	6.973	.632				.5	.292	.259			
14		.282	.026				.5					
15		.070	.007	3.0								
16	2.5			9.0	.185	.095	7.0	.004	.009			
17	2.0	.077	.011				3.0	.426	.643			
18	4.0	.938	.167									
19	3.0	.295	.042									
20	1.0	.018	.002	.5			.5					
21	2.5											
22	.5						.5					
23	5.5						5.5			1.0		
24	2.0						8.0	.740	.530			
25	7.0	2.730	.497									
26	4.5	1.186	.135	1.0								
27	9.0	.653	.088	14.5	.519	.407				.5		
28	1.5	.098	.007	3.0	.182	.072				.5		
29				.5								
30				2.0			1.0					
31				2.0								
Total	123.0	25.064	3.446	50.5	2.691	.881	65.5	3.838	3.151	46.5	4.832	3.448

TABLE A-2 (continued)

P = Daily Precipitation, mm (Main Watershed Weighing Gage)
Q = Daily Runoff, mm
S - Daily Sediment, kg/ha

	Jun 79			Jul 79		
Day	P	Q	S	P	Q	S
1				8.5		
2				.5		
3						
4				1.0		
5				1/		
6	1.0					
7						
8						
9						
10						
11	1.0					
12						
13	.5					
14						
15						
16	2.0					
17	16.0					
18	1.5					
19						
20						
21						
22						
23						
24						
25						
26	1.0					
27						
28						
29						
30	1.0					
31						
Total	24.0			10.0		

1/ Gage shut down (7/5) and removed from site.
1979 Annual Totals: P = 520.0 mm; Q = 40.8 mm;
S = 13.2 Kg/ha

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

APPENDIX B

Daily Climatic Data

TABLE B-1. DAILY MAXIMUM-MININUM TEMPERATURE DATA FOR 1977 WATER YEAR, °C
(values taken from chart to nearest 1/2°C).
Station: Rock Creek Watershed

Day	October		November		December		January		February		March	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1							-5.5	-16.5	0.0	-3.5	2.0	-2.0
2							-6.5	-12.0	4.0	-5.0	3.0	-3.0
3							-7.5	-12.0	5.0	-5.0	4.0	-2.5
4							-5.5	-17.0	2.0	-4.0	5.5	-3.0
5							-3.0	-14.0	3.0	-8.0	9.0	-3.0
6							-2.5	-14.0	3.0	-5.0	10.5	-3.0
7					1/		-3.0	-14.5	10.5	-6.0	8.0	1.0
8					4.0	0.0			10.0	-4.0	5.0	0.0
9					0.5	-1.0			7.0	-1.0	3.5	-1.5
10					3.5	-2.0	-3.0	-12.0	11.0	2.5	5.5	-4.0
11					7.0	-3.0	0.0	-6.0	11.0	4.0	6.5	-5.0
12					6.5	-4.0	0.5	-4.5	13.0	4.0	6.5	-3.0
13					6.0	-3.5	0.5	-3.5	9.0	-2.0	1.0	-9.0
14					3.0	-4.0	1.5	-1.0	10.0	-5.0	0.5	-7.0
15					8.0		4.0	1.0	13.0	-2.0	5.5	-5.5
16							7.5	1.0	13.0	3.0	7.5	-1.0
17					13.0	0.0	8.0	1.5	9.0	1.0	1.5	-4.5
18					5.5	-5.0	10.0	-1.0	12.5	0.0	3.5	-4.0
19					7.0	-5.5	8.0	-3.5	15.0	1.0	5.0	-4.5
20					6.0	-7.0	8.0	-2.5	17.0	3.0	3.0	-5.0
21					4.5	-4.0	10.5	-4.0	7.5	-1.5	7.0	0.5
22					4.0	-2.5			5.5	-0.5	15.0	-1.5
23					-1.0	-6.0			6.0	-5.0	11.0	1.0
24					0.0	-7.0			5.0	-5.0	17.0	-3.5
25					3.0	-7.0	3.0	-9.0	0.0	-3.0	8.0	-5.0
26					6.5	1.5	3.0	-8.0	3.5	-4.0	6.0	-0.5
27					7.0	-4.0	- 0.5	-7.5	4.0	-2.0	5.5	-3.0
28					7.5	-3.5	1.0	-11.5	6.0	-1.5	4.0	-4.0
29					2.5	-7.0	- 3.5	-7.0			5.0	-4.0
30					-3.0	-8.5	2.0	-10.5			10.0	-4.0
31					-7.0	-11.0	0.0	-5.5			6.0	0.0

(continued)

TABLE B-1 (continued)

Day	April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	7.0	-5.0	24.0	9.0	21.0	4.5	28.5	9.0	34.5	10.5	21.0	5.0
2	7.5	-5.0	13.5	5.0	13.5	1.0	18.5	6.0	33.0	14.0	22.0	9.0
3	12.0	-2.0	10.0	3.0	17.5	5.0	19.0	6.0	34.5	14.0	23.0	11.5
4	17.5	-1.5	7.5	0.5	17.5	9.5	12.5	1.5	30.5	15.0	23.0	14.0
5	21.0	2.0	9.5	-3.5	27.0	7.0			29.5	11.5	22.5	10.0
6	22.0	2.0	11.0	-3.5	31.0	15.0			30.5	11.0	24.0	8.0
7	24.0	5.0	16.0	1.0	26.0	17.5	26.0	2.0	31.0	9.5	23.5	8.0
8	23.0	3.0	15.0	1.5	20.0	7.0	31.0	7.0	31.5	13.0	18.0	6.0
9	8.5	-1.5	22.0	2.0	20.5	3.0	22.0	12.0	31.0	14.0	22.0	2.0
10	11.0	-4.0	12.5	2.5	22.5	6.0	22.5	3.5	30.5	13.5	24.5	6.0
11	11.0	-1.0	12.0	0.0	23.5	10.0			32.5	10.0	23.5	6.0
12	15.0	-3.0	16.0	0.5	22.0	9.5			33.5	11.0	23.0	6.0
13	9.0	-1.0	16.5	3.5	22.5	7.0			34.0	14.0	26.0	5.5
14	9.0	-3.0	10.0	4.5	24.5	7.5	27.5	8.5	32.0	13.5	21.0	8.0
15	13.5	3.0	12.0	0.5	24.0	7.0	29.0	10.0	32.5	16.0	16.5	5.5
16	8.0	-3.0	7.5	-1.0	23.5	7.0	29.5	10.5	34.0	14.0	9.5	3.0
17	7.5	-5.0	6.5	2.5	28.0	6.0	18.5	11.0	35.5	14.0	16.5	2.0
18	7.0	-5.0	8.0	2.0	30.0	11.0	16.0	9.5	35.5	14.5	20.0	10.0
19	7.0	-6.0	14.0	1.5	28.0	11.5	22.5	6.0	34.0	14.0	19.0	6.0
20	11.0	-1.0	16.0	2.5	23.0	12.0	31.0	7.5	35.5	16.0	13.5	6.0
21	13.0	1.0	16.0	4.0	23.5	10.5	30.0	13.0	28.5	14.0	13.5	6.0
22	25.0	4.0	19.0	0.5	24.5	10.0	33.0	11.5	25.0	12.0	12.5	-0.5
23	29.0	11.0	15.0	5.5	27.0	7.0	32.5	13.0	27.0	7.0	10.5	3.5
24	30.0	15.0	12.0	1.0	29.0	7.0	30.5	14.0	16.0	9.5	10.5	2.5
25	27.0	7.0	17.0	0.0	26.0	10.0	22.5	12.5	18.0	7.0	11.0	3.0
26	14.0	4.5	11.5	3.0	25.0	11.0	27.5	11.0	13.0	7.5	13.0	2.0
27	18.0	0.0	10.5	0.0	23.0	8.5	32.0	12.0	16.0	5.0	13.0	2.0
28	22.5	2.5	9.5	-1.0	26.0	6.0	25.0	12.0	15.0	6.0	12.0	8.0
29	20.0	7.0	14.5	-2.0	22.0	7.0	20.0	8.0	15.0	8.5	10.5	4.5
30	22.0	4.5	20.0	2.0	27.0	6.5	25.0	5.0	16.5	5.0	8.0	5.0
31			26.5	7.5			30.0	8.0	19.5	5.0		

[1] Instrument installed in shelter 12/7/77 - Bendix-Friez Model 594 Hygrothermograph.

TABLE B-2. DAILY MAXIMUM-MINIMUM TEMPERATURE DATA FOR 1978 WATER YEAR, ^oC
(values taken from chart to nearest 1/2^oC).
Station: Rock Creek Watershed

Day	October		November		December		January		February		March	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	13.5	0.0	11.0	1.0	8.5	- 2.5	-5.0	-21.0	2.0	-4.0	1.5	-11.0
2	14.0	1.0	4.5	-2.5	9.5	7.5	-4.0	-18.0	3.5	0.0	1.0	-9.5
3	12.5	3.5	5.5	-4.0	8.0	0.0	1.0	-10.5	7.0	1.0	0.0	-9.0
4	14.0	5.5	8.0	-4.0	1.0	-4.0	5.0	1.0	10.5	0.0	6.5	-3.5
5	14.0	1.5	7.5	1.5	-2.0	-4.5	6.0	2.0	11.0	5.0	3.5	-3.0
6	16.0	0.5	6.0	1.5	6.0	-2.5	15.0	-1.5	9.5	2.5	7.0	-1.0
7	11.0	3.0	5.0	-3.5	1.0	-6.0	4.0	-4.0	6.5	3.0	10.5	3.5
8	11.0	3.0	1.0	-6.0	-3.0	-6.0	5.5	1.5	7.5	1.0	8.0	3.5
9	8.0	-2.5	3.5	-3.0	-0.5	-5.0	7.0	1.5	4.0	-2.0	5.5	-1.5
10	10.5	-5.0	10.5	1.5	8.0	-0.5	14.5	-1.0	4.5	-3.0	8.5	-2.5
11	14.5	-2.5	14.0	6.0	8.5	2.0	0.5	-1.5	-0.5	-5.0	5.5	-2.0
12	21.0	1.5	11.0	3.0	7.0	2.5	0.0	-2.5	1.0	-7.0	3.0	-2.0
13	17.0	5.0	10.0	0.0	9.5	2.0	5.0	-2.5	1.5	-5.0	1.0	-1.5
14	18.0	2.0	7.0	-1.0	9.0	4.5	8.0	3.0	3.0	-3.0	2.5	-7.0
15	24.0	4.5	5.5	-0.5	6.0	-1.5	5.0	.5	0.0	-4.0	17.0	-9.5
16	17.0	4.5	3.0	-2.0	12.0	-1.5	5.5	1.5	2.5	-8.5	13.0	-3.0
17	19.0	2.0	-1.5	-10.0	0.0	-2.5	15.0	9.5	2.0	-9.5	18.0	3.0
18	22.0	3.0	-1.5	-10.0	-1.0	-3.0	6.0	1.0	2.0	-2.0	15.0	2.5
19	15.0	2.0			- 2.0	-11.5	3.5	1.0	5.0	0.0	14.0	1.0
20	16.0	1.0					2.0	1.0	11.5	-0.5	15.0	0.0
21	13.0	0.0			0.0	-3.5	7.5	1.0	9.0	-1.0	18.0	1.0
22	17.5	2.0			1.5	-3.5	1.0	-2.5	11.0	-1.0	16.5	5.0
23	15.5	2.0			-1.5	-7.0	-1.0	-6.5	18.0	-1.5	13.0	2.5
24	18.0	1.5	3.0	-3.0	-2.5	-7.5	0.0	-6.5	4.5	-1.0	11.0	3.0
25	9.0	4.0	11.0	0.5	-3.0	-7.5	3.0	-4.5	2.0	-1.5	13.5	3.5
26	9.5	-1.5	6.5	-1.0	-3.5	-13.5	0.0	-2.5	4.0	-1.0	16.0	2.5
27	8.5	-0.5	3.0	-2.0	-3.5	-8.0	4.5	-6.0	1.0	-1.5	15.5	3.0
28	10.0	1.0	6.0	2.0	-1.0	-5.5	2.0	-2.5	1.0	-9.0	18.0	6.5
29	9.5	2.5	8.0	-1.5	1.5	-6.5	8.5	-3.5			23.0	6.0
30	5.5	1.5	1.0	-4.0	-5.0	-11.0	1.0	-10.5			10.5	6.0
31	6.0	0.0			-6.5	-17.5	-2.0	-4.5			16.0	-1.0

(continued)

TABLE B-2 (continued)

Day	April		May		June		July		August		September	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	7.5	0.0	13.5	5.0	23.0	3.5	26.0	9.0	31.0	10.5	24.0	7.0
2	5.5	0.0	13.0	4.0	25.0	6.0	22.5	6.5	30.5	11.5	27.0	9.0
3	10.0	-1.0	6.5	1.5	27.0	9.0	16.5	10.5	31.5	14.0	29.5	10.0
4	10.0	1.0	8.0	-1.5	27.0	10.0	11.0	9.0	35.0	11.0	25.0	6.0
5	7.5	-0.5	10.5	-1.5	27.5	10.0	18.0	10.0	30.5	12.5	20.5	10.5
6	6.0	0.0	15.0	0.0	25.5	11.0	26.0	7.5	31.0	9.5	14.5	11.0
7	4.0	0.0	16.5	1.0	23.0	10.5	26.5	11.5	32.0	11.0	12.0	5.5
8	9.0	-1.0	19.5	2.5	24.0	8.0	25.0	13.0	34.0	11.0	16.5	5.5
9	12.0	-2.0	15.5	3.5	17.0	8.5	26.5	12.5	34.0	12.0	22.0	10.0
10	17.5	1.0	13.0	5.0	14.5	6.0	17.5	6.0	29.0	9.5	15.0	5.0
11	10.0	0.5	11.0	3.5	18.0	6.0	18.0	4.5			14.0	5.0
12	9.0	-2.5	12.5	1.5	22.0	12.0	23.5	4.5			12.0	3.0
13	12.5	-3.5	13.5	6.5	13.0	7.0	27.5	7.5				
14	11.5	3.5	13.0	8.0	14.5	3.5	33.0	10.5	20.0			
15	14.0	4.0	11.0	1.0	15.0	3.0	31.5	12.0	15.0	10.0		
16	9.0	0.0	7.5	1.0	16.5	1.5		10.0	15.0	6.0		
17	9.0	-0.5	12.0	4.5	22.5	3.5	21.0		16.0	7.0		
18	15.0	0.0	18.0	3.0	25.5	2.0	23.0	8.0	21.0	3.5		
19	18.0	2.0	21.5	3.5	19.0	1.0	25.0	7.0	17.0	10.5		
20	6.5	1.0	22.0	7.5	25.0	3.5	26.0	7.5	13.0	8.5		
21	8.5	0.0	21.5	5.0	25.0	6.0	29.0	9.5	20.0	7.5	12.0	3.0
22	9.0	-0.5	11.0	1.0	23.0	6.0	31.0	10.5	12.0	6.5	15.0	5.0
23	9.0	0.0	10.5	1.5	22.5	10.0	34.0	12.5	20.0	5.0	20.0	3.0
24	17.0	4.5	11.0	3.0	13.5	7.5	31.0	14.0	22.0	9.0	27.0	7.0
25	21.5	11.0	12.0	-1.5	17.0	6.0	33.0	10.0	16.0	6.0	28.0	6.5
26	15.0	8.0	16.0	-1.5	22.0	3.0	31.0	13.0	20.0	3.5	29.5	10.5
27	6.0	5.0	13.5	6.5	26.0	6.5	27.5	11.0	21.5	4.0	22.5	5.0
28	9.5	2.0	13.5	7.5	30.5	10.5	29.0	7.0	25.0	5.5	15.5	4.0
29	11.0	1.0	11.5	3.0	24.5	9.5	31.0	9.0	27.0	7.5	20.0	2.5
30	15.0	-0.5	14.0	-2.0	22.0	10.0	31.5	9.5	19.0	10.0	20.0	7.5
31			18.0	3.0			30.5	10.5	18.0	9.0		

TABLE B-3. DAILY MAXIMUM-MINIMUM TEMPERATURE DATA FOR 1979 WATER YEAR, ^{o}C (values taken from chart to nearest $1/2^{o}C$).
Station: Rock Creek Watershed

Day	October		November		December		January		February		March	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	14.5	1.5	13.0	-10.0	-0.5	-3.0			-11.5	-26.0	2.0	-6.0
2	17.5	-1.0	13.0	-4.0	0.5	-9.0			-6.0	-24.0	2.5	-4.5
3	18.0	-0.5	11.0	3.5	4.5	-4.0			-4.0	-10.5	6.0	-5.0
4	17.5	0.5	11.0	-5.0	4.5	-11.0			2.0	-6.0	6.5	1.0
5	20.0	-1.5	4.0	-9.0	-3.5	-9.5			4.5	-3.0	7.5	4.0
6	22.0	0.0	10.0	-7.0	-3.5	-15.0			4.5	-3.0	11.5	5.0
7	17.0	2.5	13.5	3.0	-5.5	-21.0			2.5	-8.5	10.0	-1.0
8	21.0	2.0	12.0	-4.0	-7.5	-16.0			5.5	-7.5	6.5	-4.0
9	22.0	4.0	2.5	-9.5	-2.0	-7.5			5.0	3.0	9.0	-5.5
10	14.0	8.0	-4.0	-11.0	1.0	-6.0			6.0	2.0	13.5	-2.5
11	13.5	4.0	-2.0	-12.0	4.0	-3.0	-2.0	-4.0	6.5	2.0	16.0	-2.0
12	13.0	-4.0	-3.0	-9.0	1.0		1.0	-8.0	8.5	1.0	10.0	-2.0
13	16.5	-5.0	0.0	-12.0				-8.5	8.0	2.0	14.0	-4.5
14	21.0	-2.0	3.0	-14.0	3.0	-4.0	-4.0	-9.0	2.0	-3.0	16.5	-1.0
15	20.0	2.0	3.0	-1.0	-0.5	-5.0			3.5	-4.0	16.0	0.5
16	17.5	2.0	4.5	-0.5	-0.5	-6.5			3.5	-2.0	4.5	0.5
17	18.0	1.5	4.0	-0.5	2.0	-1.5			4.5	-2.0	7.0	-4.0
18	20.0	1.0	1.5	-2.5	-1.0	-5.5	-5.5	-17.0	3.5	-1.0	11.0	-5.0
19	22.0	1.0	-2.5	-10.0	-4.5	-8.0	-1.5	-15.0	2.0	-4.5	12.5	-1.5
20	15.0	5.0	-6.0	-9.5	2.5	8.0	5.0	-2.0	2.5	-7.0	10.0	-2.0
21	10.0	-2.0	-2.5	-9.0	2.5	0.0	3.0	-12.0	0.0	-3.0	11.0	-3.0
22	12.0	-7.0	-4.5	-8.5	3.0	-4.0	-3.5	-6.5	2.0	-4.0	13.0	-2.0
23	15.5	-2.0	0.0	-6.0	5.0	-6.0	-1.5	-15.5	1.5	-4.0	14.0	-2.5
24	14.0	-5.0	0.0	-2.0	4.0	-8.0	-3.0	-15.0	5.0	-3.0	14.5	1.0
25	11.0	-7.0	-1.0	-4.0	-0.5	-12.5	-8.0	-15.0	5.5	2.5	8.5	1.5
26	15.5	-5.0	-1.5	-4.5	0.0	-12.5	-3.5	-11.0	6.0	1.5	7.0	1.5
27	9.5	-1.5	-0.5	-8.0	-2.0	-13.0	-4.5	-9.0	1.5	-3.0	6.0	0.0
28	14.0	-4.0	1.5	-3.5	-11.5	-20.0	-8.0	-15.0	2.5	-5.0	3.0	-1.0
29	4.0	-6.0	2.0	-1.5	-16.0	-25.0	-8.5	-21.0			4.5	-1.0
30	7.0	-7.0	2.0	-1.0	-14.0	-29.0	-8.0	-22.0			4.0	-1.0
31	10.0	-9.0					-7.5	-20.0			2.5	-2.0

(continued)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD: BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
6-1/2"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE B-3 (continued)

Day	April		May		June		July	
	Max	Min	Max	Min	Max	Min	Max	Min
1	3.0	-5.0			23.0	5.0	10.0	4.5
2	6.0	-5.0			26.0	7.5	16.0	2.5
3	4.0	-4.5	19.5	1.5	25.5	10.5	27.5	1.5
4	10.0	1.0	14.5	7.5	21.5	10.0	27.5	11.0[1/]
5	14.5	0.0	9.0	3.5	18.0	7.0		
6	8.5	2.0	10.0	-0.5	11.0	0.0		
7	9.0	-0.5	9.0	-2.5	15.0	-0.5		
8	13.0	3.0	10.5	2.5	19.5	0.0		
9	5.5	-1.0	12.5	1.0	24.0	4.0		
10	5.0	-2.5	11.0	1.5	26.0	7.5		
11	2.0	-1.0	15.0	1.0	29.5	10.5		
12	7.5	-2.5	16.0	1.0	25.5	1.0		
13	7.0	0.0	16.5	5.0	16.0	1.5		
14	8.0	-0.5	21.0	3.0	16.5	0.0		
15	9.0	0.0	22.0	6.0	18.5	1.0		
16	15.5	3.5	16.0	4.0	15.0	5.0		
17	7.0	-2.0	16.0	2.5	8.0	5.5		
18	6.0	-4.0	16.0	4.0	16.0	7.0		
19	5.0	-4.0	17.0	-0.5	15.5	5.5		
20	9.5	-5.0	20.5	1.0	18.0	3.0		
21	13.0	-4.0	21.5	6.5	19.5	3.5		
22	11.5	4.5	26.5	6.0	20.5	4.0		
23	8.5	3.5	17.0	11.0	23.0	4.0		
24	10.0	2.0	19.0	7.5	26.0	5.5		
25	13.5	2.0	23.5	5.0	29.0	8.5		
26			23.5	9.0	30.5	11.0		
27			12.0	3.0	26.5	10.0		
28	17.0		9.0	-1.5	31.5	12.0		
29	15.0	4.5	13.0	-2.0	26.0	10.0		
30	m	m	17.0	-2.0	16.0	7.0		
31			20.0	4.0				

[1/] Data collection terminated.

TABLE B-4. ROCK CREEK WATERSHED DAILY PAN EVAPORATION DATA FOR 1977 IN MILLIMETERS[1]

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					*[2]	3.6	15.4	*	*	*	0.1	
2					*	4.3	*	31.0	9.5	*	-0.3	
3					15.4	3.2	*	8.5	2.1	2.2	1.5	
4					2.8	2.6	*	*	3.5	*	0.3	
5					2.4	1.6	*	19.0	3.1	5.5	0.9	
6					2.7	*	25.7	*	*	0.7	*	
7					*	11.8	4.8	*	15.8	*	1.9	
8					5.2	3.2	7.7	24.7	*	*	1.7	
9					3.2	*	*	11.4	11.1	*	-0.3	
10					2.4	*	*	10.5	*	4.0	0.4	
11					2.2	*	*	8.1	*	*	1.7	
12					*	*	*	9.4	14.9	4.2	*	
13					5.9	23.2	37.2	*	*	*	5.0	
14					4.9	4.5	6.4	*	9.0	4.5	-0.2	
15					*	4.5	8.2	29.9	*	*	-0.3	
16					5.5	*	*	*	8.1	*	0.8[3]	
17					-0.1	*	16.3	18.8	1.0	8.7		
18					0.9	*	2.7	9.5	10.7	1.8		
19					0.0	*	1.8	*	3.5	*	*	
20					3.2	*	8.2	*	0.8	*		
21					4.2	38.5	6.7	*	2.5	6.5		
22					*	5.8	8.4	33.5	1.2	0.9		
23					9.7	7.2	*	*	1.2	*		
24					1.7	10.6	*	13.4	0.6	6.1		
25					2.5	*	20.3	*	0.8	2.1		
26					4.0	15.4	*	5.7	*	0.3		
27					2.7		9.4	5.2	*	*		
28					2.7	17.6	16.4	2.8	2.5	1.6		
29				[4]	1.5	6.3	*	1.4	0.7	*		
30				*	9.2	*	*	1.6	7.2	1.9		
31					*		*	2.6		0.6		

[1] Evaporation pan is a standard 4 foot diameter monel pan.
[2] * indicates days accumulated.
[3] Pan removed 11/16.
[4] Pan initially filled 4/29.

TABLE B-5. ROCK CREEK WATERSHED DAILY PAN EVAPORATION DATA FOR 1978 IN MILLIMETERS[1]

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1				2.0	9.1	10.3	*	29.2	*	*	1.5	
2				*	2.9	*	*	7.6	6.2	9.8	1.3	
3				1.6	4.4	*	15.9	*	*	*	0.3	
4				*	*	*	*	16.9	*	4.7	*	
5				2.1	4.7	*	-1.2	*	*	*	*	
6				*	*	*	2.0	*	17.8	6.3	3.5	
7				-0.6	*	33.4	4.6	*	0.8	*	0.9	
8				2.4	10.3	3.4	*	*	1.0	*	3.8	
9				*	*	6.2	*	40.2	*	*	[3]1.9	
10				6.3	6.9	*	*	9.7	6.4	*		
11				6.6	*	*	20.6	10.1	2.6	15.1		
12				2.4	8.0	14.8	3.3	*	1.6	*		
13				3.3	2.0	2.0	5.6	*	0.9	4.6		
14				*	*	0.8	7.0	6.7	*	*		
15				7.6	1.5	3.9	7.0	*	3.2	*		
16				-3.3	1.9	2.6	*	4.9	*	8.2		
17				3.2	-0.2	3.0	10.0	*	*	*		
18				*	*	*	4.0	*	6.6	3.5		
19				7.9	6.4	13.2	4.8	9.5	2.1	*		
20				3.0	*	5.0	7.0	2.4	1.7	5.3		
21				2.2	*	4.2	7.9	-0.1	*	*		
22				*	15.0	7.5	8.3	2.4	2.9	*		
23				7.8	*	5.3	*	0.7	*	6.4		
24				*	6.7	3.8	*	2.7	*	2.6		
25				7.1	*	*	23.2	3.3	8.3	2.6		
26				2.3	5.8	3.5	9.3	1.7	*	*		
27				-1.2	*	5.2	7.1	*	9.8	3.9		
28				0.4	*	6.7	5.4	7.1	*	*		
29				*	*	7.6	*	5.2	5.0	*		
30				*	12.9	*	*	5.1	*	3.5		
31			[2]		4.0		*	0.3		0.3		

---

[1] Evaporation pan is a standard 4 foot diameter monel pan. Readings taken at irregular times of day and days.

[2] Pan initially filled 3/31.

[3] Pan removed 11/9.

TABLE B-6. ROCK CREEK WATERSHED DAILY PAN EVAPORATION DATA FOR 1979 IN MILLIMETERS[1]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1								2.5	5.2	*		
2								2.7	*	12.0		
3								*	*	*		
4								6.2	21.4	*		
5								0.9	*	17.4		
6								1.5	13.5	[3]		
7								2.8	*			
8								1.9	7.3			
9								1.8	*			
10								*	*			
11								5.5	17.6			
12								*	*			
13								*	17.4			
14								13.9	*			
15								6.6	10.7			
16								4.2	*			
17							[2]	*	*			
18							2.9	11.0	8.1			
19							2.0	*	*			
20							1.4	*	4.2			
21							*	16.4	*			
22							*	*	10.6			
23							7.7	13.3	*			
24							0.2	1.5	*			
25							1.1	3.0	18.8			
26							*	*	*			
27							7.5		13.3			
28							*	*	*			
29							*	22.1	16.1			
30							15.4	3.4	*			
31								4.8				

---

[1] Evaporation pan is a standard 4 foot diameter monel pan. Readings taken at irregular times of day and days.

[2] Pan initially filled 4/17.

[3] Pan removed and station closed 7/5/79.

TYPING GUIDE SHEET

TABLE B-7. ROCK CREEK WATERSHED DAILY WIND RUN DATA FOR 1977 IN KILOMETERS[1]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1								*	116	73	*	*
2								*	87	*	205	100
3								336	29	*	53	32
4								255	41	*		46
5								141	33	*	155	39
6								64	*	223	*	*
7								*	88	21	*	89
8								137	74	33	184	*
9								68	*	*	83	170
10								46	*	*	81	*
11								131	*	*	62	*
12								*	*	*	54	146
13								116	193	252	*	*
14								107	39	55	*	83
15								*	28	39	195	*
16								185	*	*	*	158
17								72	*	117	110	24
18								41	*	83	52	105
19								68	*	32	*	80
20								64	*	67	*	19
21								114	263	36	*	93
22								*	54	*	242	29
23							*[2]	172	32	*	*	55
24							*	73	49	*	134	79
25							353	31	*	183	*	79
26							68	68	97	*	133	*
27							166	125	*	75	69	*
28							76	118	110	175	60	103
29							76	58	49	*	116	50
30							*	80	*	*	50	48
31								*		*	70	

---

[1] Anemometer is Science Associate Model 404 which is 3 cup N.W.S. Spec unit with contacting and counter totalizing. Readings taken at irregular times of day and correspond to evaporation readings. Anemometer height 15 cm above rim of pan, about 30 cm above soil.

[2] * indicates days accumulated.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE B-8. ROCK CREEK WATERSHED DAILY WIND RUN DATA FOR 1978 IN KILOMETERS[1]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	*	159	53	*	47	84	81	194	*	*	99	*
2	*	213	291	*	*	*	*	58	110	*	29	45
3	126	135	380	172	402	178	280	164	*	103	*	*
4	*	22	208	125	109	*	*	*	*	*	107	*
5	105	87	*	191	*	107	183	201	*	31	*	*
6	*	*	257	337	247	*	*	*	*	14	*	98
7	138	191	254	100	148	158	133	*	224	20	*	8
8	*	116	105	124	166	107	70	204	13	*	*	61
9	*	82	*	73	139	34	*	*	83	*	145	*
10	217	96	60	42	62	*	190	222	*	*	39	99
11	*	96	182	40	*	*	238	*	*	122	62	34
12	87	*	282	*	*	181	83	343	254	28	*	60
13	*	306	177	60	257	*	67	63	16	28	*	34
14	71	163	179	*	*	320	*	*	6	20	48	*
15	*	92	*	*	114	54	131	83	37	24	*	48
16	*	182	448	403	33	*	196	110	28	*	60	*
17	201	*	*	*	*	112	184	62	19	100	*	*
18	36	162	248	129	*	*	*	*	*	29	*	142
19	*	*	*	*	73	*	220	81	60	18	107	27
20	*	*	186	123	*	299	88	*	19	31	18	21
21	178	308	109	*	64	71	178	*	4	51	1	*
22	33	*	*	*	35	32	*	168	47	48	22	70
23	*	100	68	359	*	*	332	*	31	*	24	*
24	216	*	*	*	117	247	*	133	18	*	11	*
25	149	238	*	38	46	*	206	*	*	72	17	86
26	75	316	*	*	*	*	57	116	80	28	10	*
27	*	67	172	86	64	171	95	*	15	44	*	76
28	97	188	77	*	*	*	*	*	26	11	39	*
29	*	189	*	*		91	147	*	37	*	28	70
30	261	101	133	41		*	*	335	*	*	21	*
31	166		*	*		177		53		*	3	

---

[1] See 1977 notes.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA 287 (Cin.)
(4-76)

TABLE B-9. ROCK CREEK WATERSHED DAILY WIND RUN DATA FOR 1979 IN KILOMETERS[1]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	*	16	41	*	*	*	*	61	26	*		
2	166	14	*	184	25	57	402	59	*	268		
3	*	8	*	43	*	*	76	*	*	*		
4	49	*	323	*	*	198	229	114	170	*		
5	*	*	84	76	96	64	*	45	*	60		
6	58	140	20	*	106	51	229	222	315	[2]		
7	*	14	*	135	294	93	186	62	*			
8	*	194	4	*	*	*	*	66	116			
9	*	65	*	*	203	186	218	76	*			
10	*	*	*	135	135	*	*	*	*			
11	301	*	370	*	175	*	276	165	87			
12	*	*	293	78	85	205	*	*	*			
13	77	230	118	*	291	79	269	*	159			
14	*	22	*	*	121	57	*	226	*			
15	*	46	453	307	99	*	*	57	93			
16	82	*	*	*	141	125	342	96	*			
17	*	99	*	80	159	97	111	*	*			
18	37	44	383	13	223	*	110	251	80			
19	*	*	*	20	*	55	107	*	*			
20	92	165	159	*	139	*	71	*	103			
21	*	*	*	*	88	103	*	202	*			
22	*	45	587	126	*	*	*	*	68			
23	136	*	*	*	120	116	162	122	*			
24	83	6	520	38	*	*	37	42	*			
25	37	*	*	*	*	*	28	34	78			
26	*	*	93	5	404	402	*	*	*			
27	49	39	36	*	116	70	94	*	49			
28	*	79	*	*	87	68	*	*	*			
29	*	43	166	20		164	*	365	61			
30	146	128	*	*		223	190	48	*			
31	13		*	25		*		59				

---

[1] See 1977 notes.

[2] Unit removed and station shut down 7/5/79.

EPA-207 (Cin.)
(4-76)

APPENDIX C

Sample and Analytical Procedures

TABLE C-1. EPA-ARS GRAZING PROJECT, LABORATORY ANALYSES

Parameter	Samples on which analysis is performed	Preliminary treatment	Preservation	Storage Period	Method	Reference
Total coliforms	All except precipitation	None	Sample kept cool as possible before it reached lab	0–24 hrs	Membrane filter, M-coliform broth, MF endo medium	Standard Methods, 14th Edition
Fecal coliforms	All except precipitation	None	Sample kept cool as possible before it reached lab	0–24 hrs	Membrane filter, FC broth	Standards Methods, 14th Edition
Fecal streptococci	All except precipitation	None	Sample kept cool as possible before it reached lab	0–24 hrs	Membrane filter, FC streptococcal broth	Standard Methods, 14th Edition
Nitrate-Nitrite	All	Sample filtered as soon as possible (within 24 hrs) through a 0.45 µm membrane filter	Refrigeration at 4°C	0–12 wks	Auto Analyzer II Automated Cadmium Reduction Method	EPA Manual of Methods for Chemical Analysis of Water and Wastes, and Technicon Auto Analyzer II Method No. 100-70W
Nitrite	A few samples per event were checked qualitatively and if positive were analyzed quantitatively	Sample filtered soon as possible (within 24 hrs) through a 0.45 µm membrane filter	Refrigeration at 4°C	0–72 hrs	Colorimetric diazotization	EPA Manual
Ammonia, dissolved	All	None required, but since the same sample portion was used for nitrate analysis, the sample was filtered through a 0.45 µm membrane filter	Refrigeration at 4°C	0–12 wks	Auto Analyzer II Automated Colorimetric Phenate Method, modified set up for Dual NO_3 and NH_3 analysis	EPA Manual and V.L. Cochran, ARS Pullman, WA

TABLE C-1. (continued)

Parameter	Samples on which analysis is performed	Preliminary treatment	Preservation	Storage Period	Method	Reference
Total (Kjeldahl) nitrogen	Number (1) sufficient to characterize an event (based on hydrograph and NO_3^- + NH_4^+ results)	None	Refrigeration at 4 C	0-12 wks before digestion then another 0-12 weeks before analysis	Technicon BD-40 Block H_2SO_4 digestion, assayed using the Auto Analyzer II Colorimetric Phenate Method	Technicon Auto Analyzer II Industrial Method No. 376-75 W/B, and Technicon Auto Analyzer II Industrial Method No. 329-74 W/A
Total (Kjeldahl) nitrogen, dissolved	Number (2) sufficient to cover range of sample values (based on soluble NO_3^- + NH_4^+ results	Filtered immediately through 0.45 um membrane filter (same sample portion used for soluble NO_3^- + NH_4^+ analysis	Refrigeration at 4 C	3-12 wks before digestion, then another 0-12 wks before analysis	Technicon BD-40 Block H_2SO_4 digestion, assayed using the Auto Analyzer II Colorimetric Phenate method	Technicon Auto Analyzer II Industrial Method No. 376-75 W/B, Technicon Auto Analyzer II Industrial Method No. 329-74 W/A
Dissolved organic nitrogen (calculated)	Same samples as dissolved TKN	N/A	N/A	N/A	Soluble org. N calculated, Dissolved org. N = TKN dissolved - (dissolved NH_3 + NO_3^- + NO_2^--N)	N/A
Dissolved phosphorus (Orthophosphate)	All	Filtered immediately (within 24 hrs of collection) through a 0.45 um membrane filter	Frozen	0-8 wks	Colorimetric phosphomolybdate ascorbic acid single solution reagent	EPA manual
Total phosphorus	Number sufficient to characterize an event (based on hydrograph and ortho-PO_4^{3} results (1)	None	Refrigeration at 4 C	0-12 wks before digestion, then another 0-12 wks before analysis	Technicon BD-40 Block H_2SO_4 Digestion Assayed using the Auto Analyzer II Automated Colorimetric Ascorbic Acid Reduction method	Technicon Auto Analyzer II Industrial Method No. 376-75 W/B, Technicon Auto Analyzer II Industrial Method No. 329-74 W/A

TABLE C-1. (continued)

Parameter	Samples on which analysis is performed	Preliminary treatment	Preservation	Storage Period	Method	Reference
Total dissolved phosphorus	Number sufficient (1) (10-20 percent) to cover the range of values based on total P and ortho-PO_4^{-3} results	Filtered immediately (within 24 hrs of collection through a 0.45 µm membrane filter (same sample portion as used for ortho-PO_4	Refrigeration at 4°C	0-12 wks before digestion, then another 0-12 wks before analysis	BD-40 Block H_2SO_4 digestion, assayed using the Auto Analyzer II Automated Colorimetric Ascorbic Acid Reduction method	Technicon Auto Analyzer II Industrial Method No. 376-75 W/B Technicon Auto Analyzer Industrial Method No. 329-74 W/A
Dissolved organic phosphorus (calculated)	Minimum number (3) of samples (.5 percent needed to determine relative percentage of organic P to total P	Filtered immediately through a 0.45 µm membrane filter. Same sample portion as used for ortho-PO^{-3}	Frozen	0-12 wks	Dissolved hydrolyzable phosphoric determined by H_2SO_4 hydrolysis. Dissolved org. P calculated. P.D. Org. = P-D total - (P-D hydro + P-D ortho)	EPA Manual
Total organic phosphorus	"	None	Refrigeration at 4°C	0-12 wks	Total Hydrolyzable Phosphorus determined by H_2SO_4 Hydrolysis Total Org. P calculated P, Org = P, Total - (P, hydro + P ortho)	EPA Manual
Total organic carbon	All except precipitation	None	Refrigeration at 4°C	0-6 months	Combustion infrared	Analysis of TOC performed by Dr. Al Lingg, Univ. of Idaho, Dept. of Bacteriology and Biochemistry
Chemical oxygen demand	All except precipitation	None	H_2SO_4 to PH<2 Refrigeration at 4°C	0-12 wks	Normal-low level combination adapted to our COD range (≈ 10-150 mg/l)	Standard Methods, 14th Edition

TABLE C-1. (continued)

Parameter	Samples on which analysis is performed	Preliminary treatment	Preservation	Storage Period	Method	Reference
Biochemical oxygen demand (4)	All except precipitation and well samples. Some samples also had a rate BOD analysis	None	Sample kept cool as possible before it reached lab	0-24 hrs	Standard 5 days, 20°C (dissolved oxygen determined with a membrane electrode meter), Manometric BOC	Standard Methods, 14th Edition; Yellow Spring Inst. C DO Meter Instruction; HACH Chemical Manometric BOD Apparatus Instruction Manual
Sediment (suspended solids)	All	None	None	2-12 wks	Filtration except for high sediment samples were analyzed by the evaporation method	USGS Techniques of Water Resources Investigations, Book 5, Chap. CI, Lab. Theory and Method for Sediment Analysis
Solids dissolved (calculated)	Samples with high sediment concentration analyzed by the evaporation method	N/A	N/A	2-12 wks	Calculation	Same as above
pH	All	None	Sample kept cold as possible before it reached the lab for analysis	0-24 hrs	Meter	Standard Methods, 14th Edition
Specific conductance	All	None	Sample kept cold as possible before it reached the lab for analysis	0-24 hrs	Meter	Standard Methods, 14th Edition
Chloride (dissolved)	All	Sample filtered as soon as possible through 0.45 μm membrane filter	Refrigeration at 4 C	0-6 months	Coulometric-amperometric filtration with silver ions	Buchler-Cutlove Chloridometer Instruction for Operation Manual

TABLE C-1. (continued)

Parameter	Samples on which analysis is performed	Preliminary treatment	Preservation	Storage Period	Method	Reference
Sodium and potassium (dissolved)	Number sufficient (10-20 percent) to characterize the range of values based on pH, SC, and Cl⁻ results	Sample filtered through 0.45 μm membrane filter	HNO_3 to pH<2 Refrigeration at 4°C	6-12 months	Flame photometry	Standard Methods, 14th Edition
Calcium and magnesium (dissolved)	Number sufficient (10-20 percent) to characterize the range of values based on pH, SC, and Cl⁻ results	Sample filtered through 0.45 μm membrane filter	HNO_3 to pH<2 Refrigeration at 4°C	6-12 months	Atomic absorption	EPA Manual
Dissolved oxygen	Performed periodically at study streams	N/A	N/A	N/A	Membrane electrode meter	Yellow Springs Inst. Co. Model 54 ARC Co. Meter Instruction Manual
Sediment(5) phosphorus (calculated)	Number(6) sufficient (10-20 percent to cover the range of values based on total P and ortho-PO_4^{-3} results	N/A, see (4)	N/A, see (4)	N/A, see (4)	Sediment phosphorus found by calculation, sediment P = total P - total dissolved P. See (3)	
Exchangeable(7) sediment ammonia (calculated)	Minimum(6) number (<5 percent) of samples needed to determine range of values (samples were be chosen on basis of total solids)	None	Refrigeration at 4°C	0-6 months	Extraction with 2N KCl assayed using Auto Analyzer II Automated Colorimetric Phenate Method Actual sediment NH_3-N found by calculation. See (7)	Black, C. A. (Ed.) Methods of Soil Analysis
Sediment nitrogen (calculated)	Maximum number of samples needed to determine range of values (based on TKN and exchangeable sediment NH_3-N results)	N/A	N/A	N/A	Sediment N found by calculation, sediment N = TKN + exchangeable sediment NH_3-N - (dissolved NH_3+NO_2^- + NO_3-N) or Total N - Total Soluble N	

TABLE C-1. (continued)

Parameter	Samples on which analysis is performed	Preliminary treatment	Preservation	Storage Period	Method	Reference
Soil moisture	6-in increments to 72 in (or to bedrock) soil cores at 9 sites throughout the watershed	None	None	None, analysis begun immediately	Direct	Black, C. A. (Ed.) Methods of Soil Analysis
Soil nitrate	Same as above	Air dried and ground to pass 80-mesh screen	Stored in cool, dry area	0-15 months	2N KCl extraction steam distillation	Black, C. A. (Ed.) Methods of Soil Analysis
Soil ammonia	Same as above	Same as above	Same as above	0-15 months	2N KCl extraction steam distillation. Some samples assayed using Technicon Auto Analyzer II	Black, C. A. (Ed.) Methods of Soil Analysis
Soil pH	Same as above	None	None	None	1:1 water soil paste	Same as above
Soil phosphorus (available)	6-in increments to 36-in, and 12-in for the 2d 36 inches to 72-in increments (or to bedrock) of soil cores at 9 sites throughout the watershed	Air dried and ground to pass 80-mesh screen	Stored in cool, dry area	15 months	$NaC_2O_3H_3$ extraction, Colorimetric determination	Performed by Wash. State Univ. Soil Testing Lab.

---

[1] Most of the first water year's (1977) samples were depleted in determining the best procedures for other parameters. In addition, problems in developing workable TKN and Total P procedures led to only a small percentage (15 percent) of samples analyzed for these two parameters for the 1977 water year.

[2] No dissolved TKN or dissolved organic nitrogen analyses were done on 1977 water-year samples.

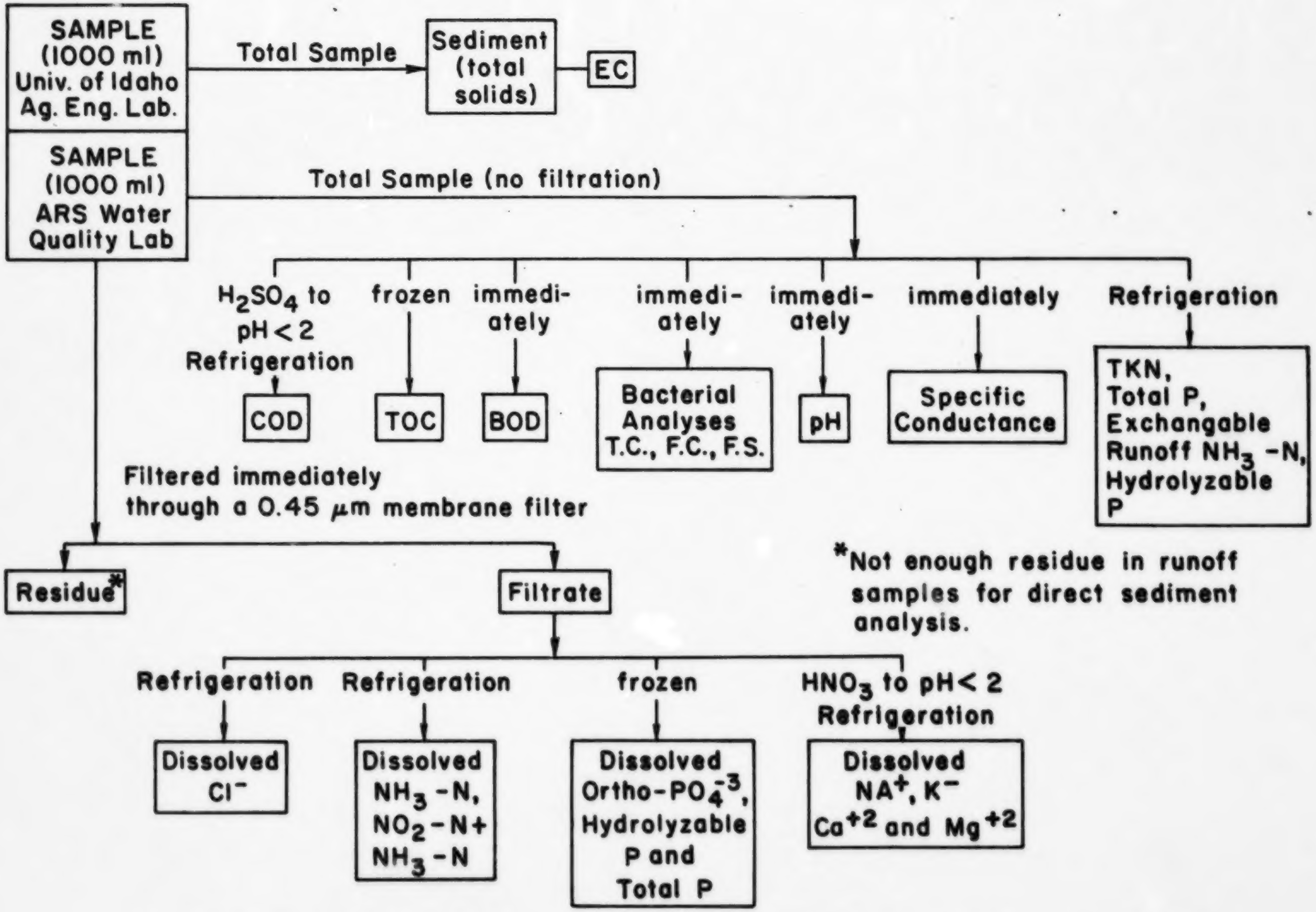
[3] No total organic phosphorus or dissolved organic phosphorus analyses were done on 1977 water-year samples.

[4] BOD test results were not reported to EPA due to uncertainty over the usefulness of the BOD. We were performing a standard BOD test in conjunction with a rate BOD test as a concurrent experiment.

[5] Sediment phosphorus (P.S.) was determined by the difference between total phosphorus (P) and total dissolved phosphorus (P-D) due to the low sediment amounts and the colloidal nature of the sediment present in the runoff. Sediment phosphorus (P-S) = total phosphorus (P) - total dissolved phosphorus (P-D).

[6] No sediment phosphorus and exchangeable sediment ammonia values were available for the 1977 water year. Attempting to concentrate enough sediment for analysis while obtaining a representative sample were not feasible given the low sediment amounts and the colloidal nature. Therefore, sediment phosphorus was found by the calculations in (6) and sediment ammonia by the calculation in (7).

[7] Due to the low amounts of sediment present in these samples, the total runoff sample (water + sediment) was extracted for ammonia. Exchangeable sediment ammonia values were found by calculation. Exchangeable sediment NH_3-N = exchangeable runoff (water + sediment) N - dissolved NH_3-N.


SAMPLE (1000 ml) Univ. of Idaho Ag. Eng. Lab.
Total Sample
Sediment (total solids)
EC
SAMPLE (1000 ml) ARS Water Quality Lab
Total Sample (no filtration)
H_2SO_4 to pH < 2 Refrigeration
COD
frozen
TOC
immediately
BOD
immediately
Bacterial Analyses T.C., F.C., F.S.
immediately
pH
immediately
Specific Conductance
Refrigeration
TKN, Total P, Exchangable Runoff NH_3 -N, Hydrolyzable P
Filtered immediately through a 0.45 μm membrane filter
Residue*
Filtrate
Refrigeration
Dissolved Cl^-
Refrigeration
Dissolved NH_3 -N, NO_2 -N+ NH_3 -N
frozen
Dissolved Ortho-PO_4^{-3}, Hydrolyzable P and Total P
HNO_3 to pH< 2 Refrigeration
Dissolved NA^+, K^- Ca^{+2} and Mg^{+2}

*Not enough residue in runoff samples for direct sediment analysis.

Figure C-1. ANALYTICAL SCHEME OF ARS-EPA GRAZING PROJECT WATER QUALITY SAMPLE MANAGEMENT

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
5-1/2"
8-1/8"

APPENDIX D

Watershed Quality Data

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE D-1. OXYGEN DEMAND, PH, SC, CL, AND CATION DELIVERY BY RUNOFF FROM THE ROCK CREEK MAIN WATERSHED FOR WATER YEAR 1977

Event dates	Water delivery	TOC	COD	BOD	pH	SC	Cl	Na	K	Ca	Mg
	m^3	--Average mg/l-				µmhos/ cm	------Average mg/l------				
1976											
Dec. 26-27	158.3	14.8	73	3.6	7.1	135	4.2	6.8	5.8	9.4	3.0
1977											
Jan. 16-19	1,795.8	22.2	111	6.1	7.2	60	2.8	3.8	5.5	7.6	2.2
Feb. 8-11	105.0	32.2	87	8.3	7.2	195	6.8	7.6	8.5	16.8	4.8
Feb. 28-Mar. 1	24.9	14.7	37	4.0	8.2	245	7.4	17.7	5.0	23.0	6.0
Mar. 7-10	65.5	16.1	38	2.6	8.1	279	7.2	21.7	5.2	24.6	5.5
Mar. 15-20	52.1	13.9	22	2.1	8.0	265	5.9	18.0	4.8	23.2	5.8
Mar. 27-28	15.7	15.8	31	2.4	8.0	265	5.8	18.0	4.6	21.3	5.0
Apr. 13-14	4.9	29.3	79	5.8	7.9	332	8.4	25.7	6.2	27.2	5.7
May 2-4	3.6	26.0	56	5.9	8.0	307	3.8	25.7	5.2	26.4	8.2
May 17-18	11.8	14.9	39	3.0	7.9	274	1.5	24.1	4.3	31.4	8.5
May 26-27	3.7	20.5	48	3.4	8.3	286	0.9	18.3	4.1	35.1	8.3
June 4	0.2	25.7	68	-	7.8	382	2.7	30.0	18.0	41.2	8.8
		----------------------kg/ha----------------------									
Total delivery	2241.5	2.2	10	0.6			0.4	0.6	0.6	1.1	0.3

EPA-287 (Cin.)
(4-76)

TABLE D-2. OXYGEN DEMAND, PH, SC, CL, AND CATION DELIVERY BY RUNOFF FROM THE ROCK CREEK CHECK WATERSHED FOR WATER YEAR 1977

Event dates	Water delivery	TOC	COD	BOD	pH	SC	Cl	Na	K	Ca	Mg
	m^3	--Average mg/l-				µmhos/ cm	------Average mg/l------				
1976											
Dec. 26–27	82.9	12.3	76	4.0	7.4	43	1.8	0.7	2.8	2.0	0.6
1977											
Jan. 16–19	206.9	13.2	50	6.2	7.0	31	1.5	0.8	3.2	4.4	1.0
Feb. 8–10	12.2	33.1	94	7.9	7.1	58	2.4	1.0	5.6	7.2	1.6
Mar. 8–9	2.6	15.9	45	1.7	7.8	30	0.6	1.8	1.7	2.3	0.9
Mar. 19	< 1.0	21.1	37	2.8	7.6	30	0.6	1.6	2.2	2.3	0.8
Mar. 27	< 1.0	15.0	15	3.0	6.9	34	0.9	3.4	1.3	3.6	1.0
	----------kg/ha----------										
Total delivery	305.0	4.7	19.9	1.9			0.5	0.3	1.1	1.3	0.3

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE D-3. OXYGEN DEMAND, PH, SC, CL, AND CATION DELIVERY BY RUNOFF FROM THE ROCK CREEK MAIN WATERSHED FOR WATER YEAR 1978

Event dates	Water delivery	TOC	COD	BOD	pH	SC	Cl	Na	K	Ca	Mg	Event type
	m^3	--Average mg/l-				µmhos/ cm	------Average mg/l------					
1977												
Oct. 30-Nov. 2	15.6	25.7	59	4.0	7.7	288	12.4	25.4	11.0	16.6	6.5	Rain
Nov. 8	22.9	70.5	701	5.6	7.9	300	15.6	35.5	11.1	22.0	8.6	Pond draining
Nov. 13-16	26.0	17.2	40	2.8	8.1	228	8.5	25.3	6.6	14.6	5.4	Rain
Nov. 25-30	304.5	9.1	28	2.9	7.4	60	1.9	7.0	3.4	4.5	1.6	Snowmelt/rain
Dec. 1-4	172.3	15.9	58	2.8	7.5	107	2.8	10.5	4.4	7.7	2.8	Snowmelt/rain
Dec. 6-7	107.2	12.5	39	3.1	7.5	99	3.5	7.9	4.2	7.1	2.5	Snowmelt/rain
Dec. 10-15	6,717.9	15.6	42	1.8	7.1	57	0.3	3.2	3.1	3.3	1.1	Rain
1978												
Jan 5-9	5,874.6	9.8	29	1.7	7.2	57	0.5	3.3	2.2	2.3	1.2	Snowmelt/limited rain
Feb. 3-7	6,699.8	12.7	37	4.2	7.3	53	0.4	3.4	1.9	2.0	1.0	Snowmelt/rain
Feb. 26-Mar. 2	1,417.5	8.1	21	2.8	7.5	71	0.3	4.7	2.0	4.8	1.5	Snowmelt/rain
Mar. 8-9	1,067.6	10.8	28	2.1	7.4	65	0.3	4.8	1.9	5.1	1.5	Rain
Mar. 12-15	1,152.4	5.3	22	1.7	7.5	67	0.6	4.8	1.7	4.3	1.5	Snowmelt
Apr. 1-7	1,518.6	13.5	35	2.5	7.5	85	0.4	5.6	1.9	7.5	2.4	Rain/sleet/snow
Apr. 16	122.7	15.9	38	3.1	7.6	100	0.2	7.5	2.0	9.8	3.2	Snow/hail/rain
Apr. 27-28	166.4	16.2	41	3.5	7.6	122	0.2	9.1	2.1	11.7	3.7	Rain
May 15-16	113.0	21.0	53	5.3	7.3	150	0.4	8.2	2.3	13.5	4.5	Rain
July 4	6.3	43.8	127	8.9	7.4	299	19.4	23.0	24.1	10.6	6.7	Rain
		------------------------kg/ha------------------------										
Total delivery	25,505	14.6	41	3.1			0.6	5.0	2.7	4.2	1.5	
Baseflow delivery	12,098	5.5	18	1.4			0.3	2.8	3.2		1.1	

EPA-287 (Cin.) (4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD. BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA

TABLE D-4. OXYGEN DEMAND, PH, SC, CL, AND CATION DELIVERY BY RUNOFF FROM THE ROCK CREEK CHECK WATERSHED FOR WATER YEAR 1978

Event dates	Water delivery	TOC	COD	BOD	pH	SC	Cl	Na	K	Ca	Mg	Event type
	m^3	--Average mg/l-				μmhos/ cm	------Average mg/l------					
1977												
Nov. 25-27	14.9	9.7	25	2.9	7.4	20	0.3	2.0	2.1	1.0	0.6	Snowmelt/rain
Dec. 1-3	15.3	13.3	39	2.9	6.6	22	0.4	1.5	2.0	2.7	1.1	Snowmelt/rain
Dec. 6-7	4.0	13.5	39	0.2	7.0	23	0.7	1.4	1.7	2.4	0.8	Snowmelt/rain
Dec. 10-16	143.0	8.7	27	1.5	6.8	23	0.1	1.9	1.7	1.4	0.6	Rain
1978												
Jan 5-9	89.3	7.5	23	1.6	6.7	27	0.3	2.0	1.3	1.9	0.7	Snowmelt/limited rain
Feb. 2-7	81.6	10.1	29	3.8	7.1	30	0.3	2.0	1.3	2.2	0.8	Snowmelt/rain
Feb. 26-Mar. 1	7.2	8.9	23	3.2	7.2	41	0.2	3.7	1.5	1.7	0.9	Snowmelt/rain
Mar. 8-9	9.6	12.6	29	1.2	7.3	51	0.2	3.8	1.3	3.0	0.9	Rain
Mar. 12-15	5.5	4.0	14	2.0	7.2	35	0.3	3.2	1.1	2.8	0.8	Snowmelt
Apr. 1-7	23.6	18.3	49	2.9	6.9	29	0.4	2.6	1.2	2.9	1.3	Rain/sleet/snow
Apr. 16	2.5	21.6	55	3.6	7.0	27	0.1	3.0	0.9	2.8	0.9	Snow/hail/rain
Apr. 27-28	4.2	24.3	45	3.8	6.7	34	0.1	4.0	2.1	6.7	2.1	Rain
May 16	5.8	21.2	47	6.7	6.9	59	0.1	3.1	2.3	4.9	1.4	Rain
		------------------------kg/ha------------------------										
Total delivery	407.0	4.5	13	1.0			0.1	1.0	0.7	0.8	0.3	

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

TABLE D-5. OXYGEN DEMAND, PH, SC, CL, AND CATION DELIVERY BY RUNOFF FROM THE ROCK CREEK MAIN WATERSHED FOR WATER YEAR 1979

Event dates	Water delivery	TOC	COD	BOD	Cl	pH	SC
	m^3	-----------Average mg/l			-----------		µmhos/cm
1978							
Nov. 4	0.9	36.7	67	8.9	16.9	7.3	302
Nov. 17	6.0	37.5	94	8.8	28.1	7.3	334
Nov. 30-Dec. 4	65.6	8.2	26	1.9	4.5	7.3	148
Dec. 11	96.7	4.0	19	1.4	1.6	6.9	69
Dec. 23-24	68.4	7.6	23	2.5	1.6	7.4	121
1979							
Feb. 6-7	51.4	13.6	29	4.8	2.8	7.2	136
Feb. 9-14	12,523.2	15.5	49	2.9	0.9	6.7	56
Feb. 18-20	1,254.6	8.9	30	1.5	0.9	7.0	73
Feb. 25-28	5,012.5	9.2	28	1.4	0.5	7.0	60
Mar. 4-8	4,968.2	6.2	26	1.5	0.5	7.0	61
Mar. 15-18	1,066.5	9.1	37	2.1	0.7	7.3	71
Mar. 27-28	532.2	10.5	45	3.5	0.7	7.4	84
Apr. 2-4	1,001.4	11.6	28	1.8	0.3	7.6	78
Apr. 6-10	2,510.2	15.0	33	2.4	0.4	7.7	75
Apr. 12-13	675.4	14.0	35	2.3	0.2	7.7	80
Apr. 16-17	631.8	13.0	39	2.4	0.3	7.7	91
Apr. 23-24	623.5	14.1	37	2.9	0.4	7.8	106
May 4-9	3,926.8	17.0	35	3.0	0.3	7.7	76
		---------kg/ha	---------				
Delivery total	35,015.0	20.5	60.2	8.6	1.1		
Baseflow	5,618.0	2.7	8.4	0.7	0.3		

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD, BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
9-1/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE D-6. OXYGEN DEMAND, PH, SC, CL, AND CATION DELIVERY BY RUNOFF FROM THE ROCK CREEK CHECK WATERSHED FOR WATER YEAR 1979

Event dates	Water delivery	TOC	COD	BOD	Cl	pH	SC
	m^3	----------Average mg/l----------					µmhos/cm
1978							
Dec. 3-4	10.2	6.9	16	3.3	0.1	6.3	13
Dec. 11	18.9	3.7	18	1.0	0.2	6.1	9
Dec. 23-24	11.1	6.8	22	2.3	0.2	6.4	13
1979							
Feb. 6-7	2.9	17.6	42	4.8	0.1	7.4	23
Feb. 9-15	170.1	6.6	17	1.5	0.2	6.5	16
Feb. 17-20	12.1	13.5	32	2.0	0.3	6.6	23
Feb. 25-28	42.4	8.2	27	1.3	0.5	6.5	24
Mar. 4-7	15.8	6.0	27	1.5	0.3	6.7	28
Mar. 16	1.7	11.2	44	2.9	0.2	6.9	37
Mar. 27-28	6.4	16.6	65	3.9	0.4	6.6	34
Apr. 2-4	4.7	11.3	36	1.7	0.6	7.2	32
Apr. 6-9	15.1	18.5	44	2.7	0.3	7.2	31
Apr. 12-13	4.2	16.4	46	3.8	0.5	6.6	27
Apr. 16-17	3.9	18.2	55	3.6	0.2	7.2	31
Apr. 24	6.7	18.8	53	3.9	0.2	7.0	39
May 4-6	43.9	18.8	40	2.9	0.3	7.3	30
		---------kg/ha---------					
Total delivery	370.0	4.0	10.69	0.8	0.1		